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<p>(54) Title: ANTAGONISTS OF HMG1 FOR TREATING INFLAMMATORY CONDITIONS</p> <p>(57) Abstract</p> <p>There is disclosed a pharmaceutical composition and method for treating sepsis, including septic shock and ARDS (acute respiratory distress syndrome), comprising administering an effective amount of an HMG1 antagonist. There is further disclosed a diagnostic method for monitoring the severity or potential lethality of sepsis or septic shock, comprising measuring the serum concentration of HMG1 in a patient exhibiting or at risk or exhibit sepsis or septic shock symptoms. Lastly, there is disclosed a pharmaceutical composition and method for effecting weight loss or treating obesity, comprising administering an effective amount of HMG1 or a therapeutically active HMG1 fragment.</p>		

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ANTAGONISTS OF HMG1 FOR TREATING INFLAMMATORY CONDITIONS

Technical Field of the Invention

The present invention provides a pharmaceutical composition and method for treating diseases characterized by activation of an inflammatory cytokine cascade, particularly sepsis, including septic shock and ARDS (acute respiratory distress syndrome), comprising administering an effective amount of an antagonist to the high mobility group 1 protein (HMG1). The present invention further provides a diagnostic method for monitoring the severity of sepsis and related conditions, comprising measuring the serum concentration of HMG1 in a patient exhibiting symptoms of a disease characterized by activation of inflammatory cytokine cascade. Lastly, the present invention provides a pharmaceutical composition and method for effecting weight loss or treating obesity, comprising administering an effective amount of an HMG1 protein or a therapeutically active fragment of the gene product of an HMG1 gene.

Background of the Invention

Sepsis is an often fatal clinical syndrome that develops after infection or injury. Sepsis is the most frequent cause of mortality in hospitalized patients. Experimental models of gram negative sepsis based on administration of bacterial endotoxin (lipopolysaccharide, LPS) have led to an improved understanding of the pathogenic mechanisms of lethal sepsis and conditions related to sepsis by virtue of the activation of a common underlying inflammatory cytokine cascade. This cascade of host-response mediators includes TNF, IL-1, PAF and other macrophage-derived factors that have been widely studied as acute, early mediators of eventual lethality in severe endotoxemia (Zhang and Tracey, In *The Cytokine Handbook*, 3rd ed. Ed. Thompson (Academic Press Limited, USA). 515-547, 1998).

Unfortunately, therapeutic approaches based on inhibiting these individual "early" mediators of endotoxemia have met with only limited success in large prospective clinical trials against sepsis in human patients. It is possible to infer from these disappointing results that later-appearing factors in the host response might critically determine pathogenesis and/or lethality in sepsis and related disorders. Accordingly, there is a need to discover such putative "late" mediators necessary and/or sufficient for part or all of the extensive multisystem pathogenesis, or for the lethality, of severe endotoxemia, particularly as endotoxemia is representative of clinical sepsis and related clinical disorders.

HMG1 is a 30 kDa chromosomal nucleoprotein belonging to the burgeoning high mobility group (HMG) of non-histone chromatin-associated proteins. As a group, the HMG proteins recognize unique DNA structures and have been implicated in diverse cellular functions, including determination of nucleosome structure and stability, as well as in transcription and/or replication. The HMG proteins were first characterized by Johns and Goodwin as chromatin components with a high electrophoretic mobility in polyacrylamide gels (see in *The HMG Chromosomal Proteins*, E.W. Johns, Academic Press, London, 1982).

Higher eukaryotes exhibit three families of HMG proteins: the HMG-1/-2 family, the HMG-14/-17 family and the HMG-I/-Y family. Although the families are distinguishable by size and DNA-binding properties, they are similar in their physical properties. HMG proteins are highly conserved across species, ubiquitously distributed and highly abundant, and are extractable from chromatin in 0.35 M NaCl and are soluble in 5% perchloric or trichloroacetic acid. Generally, HMG proteins are thought to bend DNA and facilitate binding of various transcription factors to their cognate sequences, including for instance, progesterone receptor, estrogen receptor, HOX proteins, and Oct1, Oct2 and Oct6. Recently, it has become apparent that a large, highly diverse group of proteins including several transcription factors and other DNA-interacting proteins, contain one or more regions similar to HMG1, and this feature has come to be known as the HMG1 box or HMG1 domain. cDNAs coding for HMG1 have been cloned from human, rat, trout, hamster, pig and calf cells, and HMG1 is believed to be abundant in all vertebrate cell nuclei. The protein is highly conserved with interspecies sequence identities in the 80% range. In chromatin, HMG1 binds to linker DNA between nucleosomes and to a variety of non- β -DNA structures such as palindromes, cruciforms and stem-loop structures, as well as cisplatin-modified DNA. DNA binding by HMG1 is generally believed to be sequence insensitive. HMG1 is most frequently prepared from washed nuclei or chromatin, but the protein has also been detected in the cytoplasm. (Reviewed in Landsman and Bustin, *BioEssays* 15:539-546, 1993; Baxeavanis and Landsman, *Nucleic Acids Research* 23:514-523, 1995). To date, no link has been established between the HMG proteins and any clinical condition or disease.

HMG1 has been alternatively identified as a heparin-binding protein abundantly expressed in developing brain and dubbed "amphoterin" for its highly dipolar sequence, comprising two internal repeats of a positively charged domain of about 80 amino acids (the HMG1 box) and an acidic C-terminal domain containing a stretch of approximately 30 continuous glutamic or aspartic acid residues. Amphoterin/HMG1 has been localized to the outer surface of the plasma membranes of epithelial, and especially neuronal cells, where it has been specifically localized to the filipodia of neural cells. Inhibition studies have suggested that amphoterin/HMG1 is required for process (neurite) extension and amphoterin/HMG1 also may be involved in neuron-glia interactions (Merenmies et al., *J. Biol. Chem.* 266:16722-16729, 1991; Merenmies et al., *J. Biol. Chem.* 266:16722-16729, 1991; Milev et al., *J. Biol. Chem.* 273:6998-7005, 1998; and Salmivirta et al., *Exp. Cell Res.* 200:444-451, 1992). Amphoterin/HMG1 can be released from murine erythroleukemia cells after stimulation with the chemical inducer hexamethylenebisacetamide (Melloni et al., *Biochem. Biophys. Res. Commun.* 210:82-89, 1995). Previous study suggested that the gene product of the HMG1 gene functions as a differentiation enhancing factor by stimulating α -PKC (Melloni et al., *Biochem. Biophys. Res. Commun.* 210:82-89, 1995; and Melloni et al., *FEBS Lett.* 368:466-470, 1995).

The HMG1 gene product has been shown to interact with plasminogen and tissue-type plasminogen activator (t-PA) and effectively enhance plasmin generation at the cell surface, a system that is known to play a role in extracellular proteolysis during cell invasion and tissue remodeling. Amphoterin/HMG1 has also been shown to interact with the receptor of advanced glycosylation end products (RAGE) (Mohan et al., *Biochem. Biophys. Res. Commun.* 182:689-696, 1992; Yamawaki et al., *J. Neurosci. Res.* 44:586-593, 1996; Salmivirta et al., *Exp. Cell Res.* 200:444-451, 1992; and Vassalli et al., *J. Clin. Invest.* 88:1067-1072, 1991), (Redlitz and Plow, *Baillieres Clin. Haematol.* 8:313-327, 1995; and Parkkinen et al., *J. Biol. Chem.* 266:16730-16735, 1991).

There is a longstanding need in the art to discover improved agents that can prevent the cytokine-mediated inflammatory cascade and have therapeutic activity in a large variety of cytokine-mediated inflammatory diseases. The present invention was made during the course of investigative research to identify agents that mediate toxicity, pathogenesis and/or lethality in sepsis and other disorders related by a common activation of the inflammatory cytokine cascade.

Diseases and conditions mediated by the inflammatory cytokine cascade are numerous. Such conditions include the following grouped in disease categories:

Systemic Inflammatory Response Syndrome, which includes:

Sepsis syndrome

Gram positive sepsis

Gram negative sepsis

Culture negative sepsis

Fungal sepsis

Neutropenic fever

Urosepsis

Meningococcemia

Trauma hemorrhage

Hums

Ionizing radiation exposure

Acute pancreatitis

Adult respiratory distress syndrome (ARDS)

Reperfusion Injury, which includes

Post-pump syndrome

Ischemia-reperfusion injury

Cardiovascular Disease, which includes

Cardiac stun syndrome

Myocardial infarction

Congestive heart failure

Infectious Disease, which includes

- HIV infection/HIV neuropathy
- Meningitis
- Hepatitis
- Septic arthritis
- 5 Peritonitis
- Pneumonia Epiglottitis
- E. coli 0157:H7*
- Hemolytic uremic syndrome/thrombolytic thrombocytopenic purpura
- Malaria
- 10 Dengue hemorrhagic fever
- Leishmaniasis
- Leprosy
- Toxic shock syndrome
- Streptococcal* myositis
- 15 Gas gangrene
- Mycobacterium tuberculosis*
- Mycobacterium avium intracellulare*
- Pneumocystis carinii* pneumonia
- Pelvic inflammatory disease
- 20 Orchitis/epididymitis
- Legionella
- Lyme disease
- Influenza A
- Epstein-Barr Virus
- 25 Viral associated hemophagocytic syndrome
- Viral encephalitis/aseptic meningitis
- Obstetrics/Gynecology, including:
 - Premature labor
 - Miscarriage
 - 30 Infertility
- Inflammatory Disease/Autoimmunity, which includes:
 - Rheumatoid arthritis/seronegative arthropathies
 - Osteoarthritis
 - Inflammatory bowel disease
 - 35 Systemic lupus erythematosus
 - Iridoeyelitis/uveitistopic neuritis
 - Idiopathic pulmonary fibrosis
 - Systemic vasculitis/Wegener's granulomatosis
 - Sarcoidosis

- Orchitis/vasectomy reversal procedures
- Allergic/Atopic Diseases, which includes:
- Asthma
 - Allergic rhinitis
 - 5 Eczema
 - Allergic contact dermatitis
 - Allergic conjunctivitis
 - Hypersensitivity pneumonitis
- Malignancy, which includes:
- 10 ALL
 - AML
 - CML
 - CLL
 - Hodgkin's disease, non-Hodgkin's lymphoma
 - 15 Kaposi's sarcoma
 - Colorectal carcinoma
 - Nasopharyngeal carcinoma
 - Malignant histiocytosis
 - Paraneoplastic syndrome/hypercalcemia of malignancy
- 20 Transplants, including:
- Organ transplant rejection
 - Graft-versus-host disease
 - Cachexia
- Congenital, which includes:
- 25 Cystic fibrosis
 - Familial hematophagocytic lymphohistiocytosis
 - Sickle cell anemia
- Dermatologic, which includes:
- Psoriasis
 - 30 Alopecia
- Neurologic, which includes:
- Multiple sclerosis
 - Migraine headache
- Renal, which includes:
- 35 Nephrotic syndrome
 - Hemodialysis
 - Uremia
- Toxicity, which includes:
- OKT3 therapy

Anti-CD3 therapy

Cytokine therapy

Chemotherapy

Radiation therapy

5 Chronic salicylate intoxication

Metabolic/Idiopathic, which includes:

Wilson's disease

Hemachromatosis

Alpha-1 antitrypsin deficiency

10 Diabetes

Hashimoto's thyroiditis

Osteoporosis

Hypothalamic-pituitary-adrenal axis evaluation

Primary biliary cirrhosis

15 Summary of the Invention

The present invention provides a pharmaceutical composition for treating conditions (diseases) mediated by the inflammatory cytokine cascade, comprising an effective amount of an antagonist or inhibitor of HMG1. Preferably, the HMG1 antagonist is selected from the group consisting of antibodies that bind to an HMG1 protein, HMG1 gene antisense sequences and HMG1 receptor antagonists. The present invention provides a method for treating a condition mediated by the inflammatory cytokine cascade, comprising administering an effective amount of an HMG1 antagonist. In another embodiment, the inventive method further comprises administering a second agent in combination with the HMG1 antagonist, wherein the second agent is an antagonist of an early sepsis mediator, such as TNF, IL-1 α , IL-1 β , MIF or IL-6. Most preferably, the second agent is an antibody to TNF or an IL-1 receptor antagonist (IL-1ra).

The present invention further provides a diagnostic and prognostic method for monitoring the severity and predicting the likely clinical course of sepsis and related conditions for a patient exhibiting shock-like symptoms or at risk to exhibit symptoms associated with conditions mediated by the inflammatory cascade. The inventive diagnostic and prognostic method comprises measuring the concentration of HMG1 in a sample, preferably a serum sample, and comparing that concentration to a standard for HMG1 representative of a normal concentration range of HMG1 in a like sample, whereby higher levels of HMG1 are indicative of poor prognosis or the likelihood of toxic reactions. The diagnostic method may also be applied to other tissue or fluid compartments such as cerebrospinal fluid or urine. Lastly, the present invention provides a pharmaceutical composition and method for effecting weight loss or treating obesity, comprising administering an effective amount of HMG1 or a therapeutically active fragment thereof.

Brief Description of the Drawings

Figure 1 shows two graphs that profile the induction of HMGI release by LPS *in vitro* (Figure 1A) and *in vivo* (Figure 1B). Specifically, Figure 1A shows the accumulation of HMGI in culture supernatants of macrophage RAW 264.7 cells after stimulation with LPS (100 ng/ml). The inset is a Western blot (using antibodies raised against recombinant HMGI) showing induction of HMGI release from RAW 264.7 cells after induction with TNF. Figure 1B shows accumulation of HMGI in serum of LPS-treated mice. Serum from Balb/C mice was collected at various time points after LPS administration, and assayed for HMGI by Western blotting using antibodies raised against recombinant HMGI.

Figure 2 illustrates that HMGI is a mediator of pathogenesis and lethality in endotoxemia. Figure 2A shows the protective effect of anti-HMGI antibodies against LPS lethality, tested in mice. Administration of anti-HMGI antiserum in the indicated amounts at -0.5 (if one dose), -0.5 and 12 (if two doses), or -0.5, 12 and 36 (if three doses) hours relative to LPS challenge (at time 0) was protective against LPS-induced lethality, and repeated dosing schedules provided better protection. Figure 2B illustrates that rHMGI caused dose-dependent lethality in endotoxic mice. Male Balb/C mice (20-23 grams) were randomized in groups of ten to receive LPS (3.15 mg/kg; a non-lethal dose) alone or in combination with purified recombinant HMGI protein. Administration of HMGI at the indicated doses 2, 16, 28 and 40 hours after LPS challenge significantly increased the lethality of the underlying endotoxemia. Figure 2C illustrates independent lethal toxicity of HMGI as a function of dose. Purified rHMGI was administered to male Balb/C mice (five mice per treatment group) as a single i.p. bolus at the indicated dosage. Mice were observed for at least 48 hours, and 60% of mice treated with rHMGI at a dose of 500 μ g/mouse died within 24 hours of rHMGI challenge, indicating a single dose LD₅₀ of less than 500 μ g/mouse.

Figure 3 shows that HMGI induced TNF release both *in vitro* (Figure 3A) and *in vivo* (Figure 3B). Specifically, Figure 3A shows that HMGI induces TNF release from huPPBMCs in dose-dependent fashion. Freshly isolated huPBMC cultures were stimulated with purified recombinant HMGI protein at the indicated doses, and culture media were sampled four hours later to be assayed for TNF according to known immunologic methods (ELISA). Figure 3A shows the mean \pm S.E.M. of the induced TNF response in two experiments (in triplicate). Figure 3B shows that administration of HMGI induced accumulation of TNF in serum of treated mice. Balb/C mice (20-23 g) were treated intraperitoneally with purified recombinant HMGI at the indicated doses and blood samples were taken two hours later for assay of TNF by an L929 bioassay and (TNF levels expressed as mean \pm S.E.M., N=3).

Figure 4 shows that HMGI caused body weight loss in mice. Purified HMGI was administered intraperitoneally to mice at 100 μ g/mouse/day for three days, and body weight was monitored. Figure 4 shows the mean \pm S.E.M. of net body weight change of three mice per group.

Figure 5 shows the tissue distribution of HMGI mRNA. Human RNA master blots containing poly(A)⁺ RNA of various tissues (Clontech, Palo Alto, CA, USA) were hybridized

with a 0.6 kb digoxigenin-11-dUTP-labeled HMG1 cDNA probe synthesized by PCR using recombinant plasmid containing the HMG1 cDNA insert, all in accordance with methods well-known in the art. Briefly, hybridization was performed in a hybridization buffer (5X SSC/2% blocking reagent/0.1% SDS/50% formamide, Boehringer Mannheim, Indianapolis, IN) with a probe concentration of 10 ng/ml for 16 hours at 65 °C. After hybridization, the filter was subjected to two washes of 0.5X SSC/0.1% SDS for 5 minutes, and two washes of 0.2X SSC/0.1% SDS for 10 minutes at room temperature. Signal was detected using anti-digoxigenin antibodies conjugated to phosphatase and detection reagents 4-nitrobluetetrazolium chloride (NBT) and 5-cromo-4-chloro-3-indolyl-phosphate (BCIP) (Boehringer-Mannheim) according to standard methods. The blots were scanned with a silver image scanner (SilverScanner II, Lacie Limited, Beaverton, OR), and relative optical density (in arbitrary units, AU) was quantified using NIH 1.59 image software. Note that highest levels were observed in macrophage-rich tissues.

Figure 6 shows, in comparison to a group of normal control subjects, increased human serum HMG1 levels as detected in hospitalized human subjects with sepsis, wherein the septic patients have been further categorized as to whether the patient died or survived.

Detailed Description of the Invention

The present invention is based upon the discovery and isolation of a highly inducible 30 kDa protein that is released by, and accumulates in media conditioned by, cultured murine macrophage-like cells (RAW 264.7) following stimulation with LPS, TNF, or IL-1. A partial amino acid sequence of this isolated polypeptide was identical to the sequence of the HMG1 protein, also known as amphoterin, a protein not before linked to the pathogenesis of any disease. This information was used to clone a cDNA encoding HMG1, which sequence was expressed to provide recombinant protein, which protein was used to generate specific anti-HMG1 antibodies.

Therapeutic and diagnostic efficacy was determined in a series of predictive *in vitro* and *in vivo* experiments. The experiments are detailed in the Examples section. For example, following administration of endotoxin (LD₁₀₀) to mice, serum HMG1 levels increased later (at 16 h) than well-known "early" mediators of sepsis (such as TNF and IL-1) and plateau levels of HMG1 were maintained for 16 to 32 hours. Patients with lethal sepsis had high serum HMG1 levels, which were not detected in normal healthy volunteers. Moreover, acute experimental administration of rHMG1 to test animals, whether alone or in combination with sub-lethal amounts of LPS, caused marked pathological responses and even death. More distributed dosing schedules of lower amounts of rHMG1 led to significant weight loss in treated animals. These results give evidence that HMG1 is a mediator of endotoxemia and particularly a late mediator, as opposed to known "early" mediators such as TNF and IL-1. These data further show the importance of serum HMG1 as a marker for the severity or potential lethality of sepsis and related conditions.

In addition, treatment with anti-HMG1 antibodies provided full protection from LD₁₀₀ doses of LPS in mice. HMG1 is inducible by TNF and IL-1 β , and dose-dependently stimulates TNF release from huPBMCs. TNF is a marker of macrophage activation, so it is likely (without limitation as to implied mechanisms or being bound by theory) that HMG1 promotes downstream re-activation of cytokine cascades which, in turn, mediates late pathogenesis and lethality in sepsis and related conditions involving activation of pro-inflammatory cytokine responses. Thus, HMG1 likely occupies a central role in mediating the inflammatory response to infection and injury, and antagonists of HMG1 will be of therapeutic benefit in sepsis and related conditions of inflammatory cascade activation. The appearance of HMG1 in the inflammatory cytokine cascade is suitable to propagate later phases of the host response and contribute to toxicity and lethality. The predictive data provided herein support the therapeutic efficacy of HMG1 antagonists and provide evidence in support of the aforementioned theory regarding mechanism of action. The *in vivo* treatment data showed the efficacy of HMG1 antagonists in general, and anti-HMG1 antibodies in particular, for treating conditions mediated by the inflammatory cytokine cascade in general and particularly sepsis conditions, including, for example, septic shock, sepsis syndrome or other "sepsis-like" conditions mediated by inflammatory cytokines. Further, the independent pathogenicity and toxicity/lethality of HMG1 shows that HMG1 antagonists are particularly effective when co-administered with antagonists of "early" inflammatory mediators such as TNF, MIF, IL-1 and IL-6.

In summary, HMG1 is a cytokine mediator of inflammatory reactions because: 1) HMG1 is released from macrophages and pituicytes following stimulation with bacterial toxins or with pro-inflammatory cytokines (TNF or IL-1 β); 2) HMG1 accumulates in serum of animals exposed to LPS and in patients with sepsis; and 3) HMG1-specific antibodies protect against mortality in a predictive lethal endotoxemia animal model of clinical sepsis and related conditions.

Pharmaceutical Composition and Method of Administration

The inventive pharmaceutical composition or inventive pharmaceutical combination can be administered to a patient either by itself (complex or combination) or in pharmaceutical compositions where it is mixed with suitable carriers and excipients. The inventive pharmaceutical composition or inventive pharmaceutical combination can be administered parenterally, such as by intravenous injection or infusion, intraperitoneal injection, subcutaneous injection, or intramuscular injection. The inventive pharmaceutical composition or inventive pharmaceutical combination can be administered orally or rectally through appropriate formulation with carriers and excipients to form tablets, pills, capsules, liquids, gels, syrups, slurries, suspensions and the like. The inventive pharmaceutical composition or inventive pharmaceutical combination can be administered topically, such as by skin patch, to achieve consistent systemic levels of active agent. The inventive pharmaceutical composition or inventive pharmaceutical combination can be formulated into topical creams, skin or

mucosal patches, liquids or gels suitable for topical application to skin or mucosal membrane surfaces. The inventive pharmaceutical composition or inventive pharmaceutical combination can be administered by inhaler to the respiratory tract for local or systemic treatment.

5 The dosage of the inventive pharmaceutical composition or inventive pharmaceutical combination of the present invention can be determined by those skilled in the art from this disclosure. The pharmaceutical composition or inventive pharmaceutical combination will contain an effective dosage (depending upon the route of administration and pharmacokinetics of the active agent) of the inventive pharmaceutical composition or inventive pharmaceutical combination and suitable pharmaceutical carriers and excipients, which are suitable for the
10 particular route of administration of the formulation (*i.e.*, oral, parenteral, topical or by inhalation). The active agent is mixed into the pharmaceutical formulation by means of mixing, dissolving, granulating, dragee-making, emulsifying, encapsulating, entrapping or lyophilizing processes. The pharmaceutical formulations for parenteral administration include aqueous solutions of the active agent or combination in water-soluble form. Additionally,
15 suspensions of the active agent may be prepared as oily injection suspensions. Suitable lipophilic solvents or vehicles include fatty oils such as sesame oil, or synthetic fatty acid esters, such as ethyl oleate or triglycerides, or liposomes. Aqueous injection suspensions may contain substances that increase the viscosity of the suspension, such as sodium carboxymethyl cellulose, sorbitol, or dextran. The suspension may optionally contain stabilizers or agents to
20 increase the solubility of the active agent or combination to allow for more concentrated solutions.

Pharmaceutical formulations for oral administration can be obtained by combining the active agent with solid excipients, such as sugars (*e.g.*, lactose, sucrose, mannitol or sorbitol), cellulose preparations (*e.g.*, starch, methyl cellulose, hydroxypropylmethyl cellulose, and
25 sodium carboxymethyl cellulose), gelatin, gums, or polyvinylpyrrolidone. In addition, a disintegrating agent may be added, and a stabilizer may be added.

Antisense Oligomers

The present invention provides antisense oligomers having a sequence effective to inhibit or block the expression of the HMG1 gene or mRNA sequence. Antisense technology,
30 which uses specific- oligonucleotides to inhibit expression of target gene products, is developing as a therapeutic modality for human disease. Several selection criteria are available to contribute to the optimization of antisense oligonucleotide antagonists. For example, it is advisable to choose sequences with 50% or more GC content. Preferred sequences span the AUG initiation codon of the target protein, but sites in the coding region and 5' UTR may
35 perform equally well. Such sequences are generally about 18-30 nucleotides long and chosen to overlap the ATG initiation codon from the HMG1 cDNA sequence to inhibit protein expression. Longer oligomers are often found to inhibit the target to a greater extent, indicating that a preferred length is about 25 mer for the first oligonucleotides chosen as antisense reagents. Typically, three oligonucleotide sequences are chosen with regard to these

criteria, and compared for antagonist activity to control oligonucleotide sequences, such as "reverse" oligonucleotides or those in which about every fourth base of the antisense sequence is randomized. Therefore, a preferred sequence for making antisense oligomer sequences to HMG1 is a 25 mer sequence chosen to overlap the ATG initiation codon (underlined) from the HMG1 cDNA sequence:

GAGGAAAAATAACTAAACATGGGCAAAGGAGATCCTAAGAAG [SEQ ID NO. 5]

and such preferred antisense sequences are used to construct antisense oligonucleotide agents (and suitable controls) for an *in vitro* comparison as antagonists of HMG1. These *in vitro* data are predictive of human clinical utility using antisense agents of comparable design.

HMG1-directed Antibodies

The antibodies disclosed herein may be polyclonal or monoclonal; may be from any of a number of human, non-human eukaryotic, cellular, fungal or bacterial sources. The antibodies may be encoded by genomic or vector-borne coding sequences, and may be elicited against native or recombinant HMG1 or fragments thereof with or without the use of adjuvants. The methods for making antibodies are methods and procedures well-known in the art for generating and producing antibodies. Generally, neutralizing antibodies against HMG1 (*i.e.*, those that inhibit biological activities of HMG1 particularly with regard to its pro-inflammatory cytokine-like role) are preferred for therapeutic applications while non-neutralizing antibodies may be as suitable for diagnostic applications. Examples of such useful antibodies include but are not limited to polyclonal, monoclonal, chimeric, single-chain, and various human or humanized types of antibodies, as well as various fragments thereof such as Fab fragments and fragments produced from specialized expression systems.

Diagnostic Assay

The diagnostic assay provided here uses anti-HMG1 antibodies that can be either polyclonal or monoclonal or both. The diagnostic procedure can utilize standard antibody-based techniques for measuring concentrations of the gene product of HMG1 genes in a biological fluid. Preferred standard diagnostic procedures are ELISA assays and Western techniques.

Example 1: Identification of HMG1 as a "late" mediator of endotoxemia

This example provides the results of an experiment to identify and isolate later released macrophage-derived factors that play a role in sepsis and in related conditions typified by inflammatory cytokine activity. The experiment reported in this example examined murine macrophage RAW 264.7 cell-conditioned media after stimulation of the cultures with TNF. Murine macrophage RAW 264.7 cells were obtained from American Type Culture Collections (ATCC, Rockville, MD, USA), and proliferated in culture under DMEM supplemented with 10% fetal bovine serum and 1% glutamine. When confluency reached 70-80%, the medium was replaced by serum-free OPTI-MEM I medium and cultures were stimulated with pro-inflammatory cytokines (*e.g.*, TNF α or IL-1) or bacterial endotoxin (LPS).

The proteins released from the above stimulated macrophage cultures were surveyed. Specifically, at different time points, cells and cell-conditioned media were separately collected by centrifugation (3000 rpm, 10 minutes). Proteins in the conditioned medium were concentrated by ultrafiltration over Amicon membranes with Mr cutoff of 10 kDa (Amicon Inc., Beverly, MA, USA), subsequently fractionated by SDS-PAGE, and stained with Coomassie blue (1.25% Coomassie Blue R250 in 30% methanol/10% acetic acid). After destaining with 30% methanol/7% acetic acid, protein(s) of interest (*i.e.*, those that preferentially accumulated in conditioned media of stimulated cultures) was isolated by excision from the SDS-PAGE gel, and subjected to N-terminal sequencing analysis (Commonwealth Biotechnologies, Inc., Richmond, VA, USA).

Comparison of SDS-PAGE gel analysis of profiles of proteins accumulated in control (without TNF α stimulation) versus TNF-stimulated RAW 264.7 cells revealed a strongly inducible 30 kDa protein whose concentration in the cell-conditioned medium was significantly increased after stimulation for 16 hours. Amino acid sequence analysis of this isolated protein revealed its N-terminal sequence as Gly-Lys-Gly-Asp-Pro-Lys-Lys-Pro-Arg-Gly-Lys-Met-Ser-Ser [SEQ ID NO. 1]. A review of relevant gene databases found a 100% identity to the N-terminal amino acid sequence of HMG1.

These data identified HMG1 as a "late-appearing" product of LPS-stimulated macrophage cultures, and therefore as a candidate pro-inflammatory mediator. This activity was confirmed by administration of recombinantly produced HMG1 and/or of anti-HMG1 antibodies in cellular and animal model systems that are predictive of human clinical conditions.

Example 2: Cellular sources of HMG1

This example shows which cell sources are capable of releasing HMG1 in response to TNF, IL-1 and/or LPS. Cells studied include GH₃ pituitocytes, murine macrophage RAW 264.7 cells, human primary peripheral blood mononuclear cells (huPBMCs), human primary T cells, rat adrenal PC-12 cells, and rat primary kidney cells (Table 1). The rat pituitary GH₃ cell line was obtained from American Type Culture Collection (ATCC, Rockville, MD, USA), and cultured in DEME supplemented with 10% fetal bovine serum and 1% glutamine. Human PBMCs and T cells were freshly isolated from whole blood of healthy donors and cultured in RPMI 1640 supplemented with 10% human serum as previously described (Zhang et al., *J. Exp. Med.* 185:1759-1768, 1997). When confluency reached 70-80%, the medium was replaced by serum-free OPTI-MEM I medium and cultures stimulated with proinflammatory cytokines (*e.g.*, TNF α or IL-1) or bacterial endotoxin (LPS).

Although human T cell, rat adrenal (PC-12) cells, and rat primary kidney cells contained cell-associated HMG1 as demonstrated by Western blotting analysis of whole cell lysates using HMG1-specific antibodies (see example 4 below), HMG1 did not significantly accumulate in the medium of these cultures after stimulation with either TNF, IL-1 β , or LPS (Table 1).

Table 1. Induced release of HMGI from various types of cells.

Cell Type	Stimulus		
	TNF	IL-1 β	LPS
Murine RAW 264.7 cells	Yes	Yes	Yes
Human PBMCs	Yes	Yes	Yes
Human primary T cells	No	No	No
Rat adrenal PC-12 cells	No	No	No
Rat pituitary GH ₃ cells	Yes	Yes	No
Rat primary kidney cells	No	No	No

Note: PBMCs, peripheral blood mononuclear cells.

TNF, IL-1 β (minimal effective concentration = 5 ng/ml for each) and bacterial endotoxin (LPS, minimal effective concentration = 10 ng/ml) induced the release of HMGI from human PBMCs in a time- and dose-dependent manner (Table 1). IFN- γ alone (0-200 U/ml) did not induce HMGI release from any of the above cells, but when added in combination either with TNF or IL-1 β , IFN- γ dose-dependently enhanced HMGI release from macrophages, with a maximal 3-fold enhancement by IFN- γ at a concentration of 100 U/ml. The release of HMGI was not due to cell death, because cell viability was unaffected by TNF, IL-1 β , or LPS, as judged by trypan blue exclusion (90-92 \pm 5% viable for control vs. 88-95 \pm 4% in the presence of 100 ng/ml TNF, IL-1 β or LPS). The amount of HMGI released by pituitocytes and macrophages inversely correlated with the intracellular concentration of HMGI, as determined by Western blotting analysis, indicating that the released material is, in part, derived from pre-formed cell-associated HMGI protein.

Potential sources of circulating HMGI *in vivo* were assessed by hybridization of an HMGI-specific probe to mRNA prepared from various normal human tissues (blot substrate available from commercial sources), with the results summarized in Figure 5. Several macrophage-rich tissues (lung, liver, kidney, pancreas and spleen) exhibited the most abundant HMGI mRNA expression; less was observed in pituitary, bone marrow, thymus, lymph node and adrenal gland. In addition to providing information as to the relative tissue distribution of HMGI expression, this study shows the practicality and utility of assaying for HMGI-specific nucleic acid sequences in tissue samples.

Example 3: Recombinant HMGI Administration, *in vitro* and *in vivo*

This example details procedures to produce HMGI by well-known recombinant DNA technologies. The HMGI open reading frame was amplified by PCR and subcloned into an expression vector (pCAL-n). Briefly, the 648-bp open reading frame of HMGI cDNA was PCR amplified (94 °C 1', 56 °C 2', 72 °C 45", 30 cycles) from 5 ng Rat Brain Quick-Clone cDNA (Catalog # 7150-1, Clontech, Palo Alto, CA, USA) using primers containing the following sequences, 5'- CCC GCG GAT CCA TCG AGG GAA GGA TGG GCA AAG GAG ATC CTA -3' [SEQ ID NO. 2], and 5'- CCC GCA AGC TTA TTC ATC ATC ATC ATC TTC

T -3' [SEQ ID NO. 3]. The 680 bp PCR product (4 µg) was digested with *Bam* HI and *Hind* III, and cloned into the *Bam* HI/*Hind* III cloning sites of the pCAL-n vector (Stratagene, La Jolla, CA, USA). The recombinant plasmid was transformed into *E. coli* BL21(DE3)pLysS (Novagen, Madison, WI, USA), and positive clones were screened and confirmed by DNA
5 sequencing on both strands using a Tag DyeDeoxy terminator cycle sequencing kit on the ABI 373A automated fluorescent sequencer (Applied Biosystems, Foster City, CA, USA).

To express recombinant HMG1, positive clones were cultured at 37 °C with vigorous shaking (250 rpm) until OD₆₀₀ reached 0.6, when IPTG (1 mM) was added. Twelve hours after IPTG induction, bacterial cells were harvested by centrifugation (6500 rpm, 15 minutes),
10 and lysed by freeze-thaw cycles. The water-soluble fraction was collected after centrifugation (30 minutes, 12,000 rpm), and recombinant HMG1 was purified on a calmodulin-binding resin column as instructed by the manufacturer (Stratagene). Bacterial endotoxin was removed from the recombinant HMG1 by using Detoxi-Gel endotoxin-removing gel (Pierce, Rockford, IL
USA, Cat. #20344), and residual LPS content was determined by the Limulus Amebocyte
15 Lysate Test (LAL test, Cat. # 50-648U, QCL-1000 Chromogenic LAL, Bio-Whittaker, Inc., Walkersville, MD, USA). Purified recombinant HMG1 was added to cultures of human peripheral blood mononuclear cells (HuPBMCs), and supernatants assayed for TNF by ELISA four hours after stimulation. The LPS-neutralizing agent polymyxin B (10 µg/ml) was added concurrently with recombinant HMG1 to eliminate the effect of any contaminating LPS on
20 TNF release. Additionally, recombinantly derived HMG1 was administered to test animals, with or without the additional endotoxemic challenge of exogenous LPS, to study the pathogenic potential of high levels of HMG1 *in vivo* (see Figures 2B and 2C). In some experiments, serum samples were secured from HMG1-treated animals to be assayed for TNF as detailed herein (see Figure 1B).

25 The above procedure provides recombinant HMG1 as a fusion peptide comprising a 3.0 kDa calmodulin-binding domain and a thrombin cleavage site as an amino terminal extension in register with the HMG1 peptide sequence. In some experiments, the fusion tag was removed from an aliquot of the recombinant protein and the bioactivity of the full fusion protein was compared to the cleaved HMG1 peptide; no significant difference in bioactivity
30 was noted and additional experiments (especially those requiring administration of recombinantly produced HMG1 to animals) typically were conducted with the (uncleaved) fusion protein.

As demonstrated in Figures 3A and 3B, *in vitro* or *in vivo* administration of recombinantly derived HMG1 induced a brisk TNF response, confirming the identification of
35 HMG1 as a late-appearing LPS-induced macrophage-derived endogenous mediator with pro-inflammatory activity.

Example 4: Anti-HMG1 antibodies and immunodetection

This example provides the results of experiments to generate and use polyclonal antibodies against HMG1. Briefly, polyclonal antibodies against an oligopeptide

corresponding to the N-terminal amino acid sequence of HMG1, or against purified recombinant HMG1, were generated in rabbits according to standard procedures well known in the art. Briefly, eight copies of an oligopeptide with the sequence GKGDPPKKPRGKMSSC [SEQ ID NO. 4] were anchored to radially branching lysine dendrites (small immunogenically inert core). These large macromolecules were injected three times both subcutaneously and intradermally (0.5 -1.0 mg per injection) into rabbits at week 1, 2, and 4 after pre-bleed at Day 0. Two weeks after the last immunization, rabbits were bled and boosted intramuscularly with 1.0 mg of antigen, followed by a second bleeding two weeks later. Alternatively, to produce polyclonal antibodies against recombinant HMG1, rabbits were immunized with recombinant HMG1 fusion peptide (100 µg per injection) following a similar protocol. Monoclonal antibodies reactive against HMG1 (*i.e.*, that bind, and in some cases, neutralize or antagonize the biological activity of HMG1) are conveniently prepared according to methods well known in the art using the HMG1 antigens described herein or other HMG1 peptide fragments as immunogens. Such monoclonal antibodies, and/or the hybridomas that produce them, are useful to produce various "humanized" antibodies reactive against HMG1 (all according to methods known in the art), which humanized antibodies are useful as taught herein.

HMG1-specific antibodies were used to measure by Western blotting analysis the inducible release of HMG1 from RAW 264.7 cells after treatment with TNF or LPS (Figure 1). Briefly, proteins were fractionated by SDS-PAGE on a 4-20% gradient gel, transferred to a PVDF membrane, and blotted with rabbit antiserum raised against either the N-terminal synthetic HMG1 antigen or against recombinant HMG1. The signal was detected using a ECL kit as instructed by the manufacturer (Amersham Life Science Inc., Arlington Heights, IL, USA), and levels of HMG1 were determined by measuring optical intensity of bands on Western blots digitized for analysis using NIH 1.59 image software, with reference to a standard curve of purified recombinant HMG1.

No HMG1 protein was detected in RAW 264.7 cells-conditioned medium in the absence of TNF or LPS treatment, but HMG1 accumulated in conditioned medium to high levels after such stimulation, reaching a plateau at 8-28 hours after stimulation (Figure 1A). In summary, the data presented in Examples 1, 3 and in Figure 1A show that the release of HMG1 from macrophages is stimulus-specific and time- and dose-dependent, with maximal accumulation observed within 8 hours after stimulation with TNF at concentrations as low as 5 ng/ml. It is well appreciated that sepsis, septic shock and related conditions may occur in humans in response to stimuli that differ qualitatively or quantitatively from the single large, lethal LPS bolus used in this predictive model. Nevertheless, experimental endotoxemia has been a valuable and predictive model system by which to identify critical components of the inflammatory cytokine cascade and by which to identify specific antagonists with predicted clinical utility. In this regard, HMG1 antagonists are perhaps more therapeutically attractive than TNF antagonists in view of the later appearance of HMG1 versus TNF in the response to endotoxin.

Example 5: Detection of HMG1 in *in vivo* animal models

This example illustrates an *in vivo* experiment in rodents measuring serum HMG1 levels after administration of a sublethal dose of LPS (LD₅₀). Mice or rats were treated with LPS, and sera were collected at different time points, and assayed for levels of HMG1 by Western blotting analysis. The serum concentrations of HMG1 were estimated by measuring the optical band intensity with reference to a standard curve of purified HMG1. Serum levels increased significantly by 16 hours after LPS, and remained high for at least 32 hours (Figure 1B), and were not detectable in vehicle-treated control animals. These data show that HMG1 represents a particularly attractive target for diagnosis of, and pharmaceutical intervention against, sepsis and related disorders of cytokine toxicity because HMG1 is a late-appearing mediator in the inflammatory cytokine cascade.

Example 6: Benefits of protection against HMG1

This example provides the results of a predictive *in vivo* assay to measure therapeutic activity of antagonists of HMG1 in relation to treatment of sepsis and related conditions of cytokine-mediated toxicity. In this example, the HMG1 antagonist was an anti-HMG1 antibody preparation. Controls treated with pre-immune serum developed lethargy, piloerection, diarrhea, and succumbed to death within 48 hours. These clinical signs of endotoxemia were significantly prevented by administration of anti-HMG1 antibodies. Male Balb/C mice (6-7 weeks, 20-23 grams) were randomly grouped (10 animals per group) and pre-treated either with control (pre-immune) or anti-HMG1 serum (as made in Example 4) 30 minutes before administration (intraperitoneally) of a lethal dose of LPS (50 mg/kg in 1 x PBS). Other experimental groups received additional doses of anti-HMG1 serum at +12 or, +12, and +36 hours after LPS administration. Animals were observed for appearance and survival for at least two weeks.

Polyclonal antibodies against recombinant HMG1 were generated in rabbits, and antiserum was assayed for specificity and titer by ELISA and Western blotting procedures. The polyclonal antiserum immunospecifically recognized (bound to) recombinant HMG1 in Western blot analysis, for instance, and discriminated rHMG1 from other proteins in both crude bacterial lysates and as a purified protein that had been diluted into mouse serum. Using chemiluminescence-amplified detection methods in Western blotting analysis, polyclonal anti-HMG1 antiserum at dilutions up to 1:1000 was useful to detect as little as 50 pg rHMG1 protein. Administration of anti-HMG1 antiserum in the indicated (Figure 2A) amounts at -0.5 (if one dose), -0.5 and 12 (if two doses), or -0.5, 12 and 36 (if three doses) hours relative to LPS challenge (at time 0) was protective against LPS-induced lethality, and repeated dosing schedules provided better protection.

Figure 2B illustrates that rHMG1 causes dose-dependent lethality in endotoxic mice. Male Balb/C mice (20-23 grams) were randomized in groups of ten to receive LPS (3.15 mg/kg; a non-lethal dose) alone or in combination with purified recombinant HMG1 protein.

Administration of HMGI at the indicated doses 2, 16, 28 and 40 hours after LPS challenge significantly increased the lethality of the underlying endotoxemia.

Figure 2C illustrates the independent lethal toxicity of HMGI as a function of dose. Purified rHMGI was administered to male Balb/C mice (five mice per treatment group) as a single i.p. bolus at the indicated dosage. Mice were observed for at least 48 hours, and 60% of mice treated with rHMGI at a dose of 500 μ g/mouse died within 24 hours of rHMGI challenge, indicating a single dose LD₅₀ of less than 500 μ g/mouse.

The protection conferred by anti-HMGI antibodies was specific, because administration of pre-immune serum, which showed no immunospecific reactivity to HMGI on Western blots, did not spare subjects from LPS-mediated mortality (Figure 2A). Moreover, HMGI-specific antibodies did not cross-react with other macrophage-derived cytokines (*e.g.* IL-1 and TNF), eliminating the possibility that antibodies conferred protection by binding and thereby neutralizing these mediators. Protection against sepsis, sepsis associated pathogenesis and sepsis-related diseases involving activation of pro-inflammatory cytokine cascades may be improved by combination therapy targeted against more than one component of the cytokine cascade. Antagonists of HMGI in this regard can be combined with specific antagonists of TNF, IL-1, MIF and other inflammatory mediators, or with more broadly active antagonists of inflammatory responses that inhibit multiple components of the inflammatory cascade (*e.g.*, aspirin, NSAIDS, anti-inflammatory steroids, etc.), to provide even more effective therapeutic modalities. Protection against LPS toxicity was antibody dose-related, and more frequent dosing with higher amounts of antibody reduced mortality by up to 70% (Figure 2A). Mice were observed for at least 2 weeks in all experiments, and no late mortality occurred, indicating that anti-HMGI antibody treatment confers lasting protection against LPS lethality, and does not merely delay the time of death.

Example 7: HMGI in human disease

This example provides data that establish an association between HMGI and human sepsis, and thereby support an indication for using HMGI antagonists generally and anti-HMGI antibodies in particular in human sepsis and related conditions of cytokine toxicity. Serum HMGI levels in normal healthy individuals and critically ill patients were measured using the polyclonal antibodies generated as in Example 4 in a Western blot format with reference to a standard curve of rHMGI. HMGI was not detectable in normal controls, but accumulated to high levels in critically ill patients with sepsis (Table 2).

Table 2. Serum appearance of HMGI in sepsis patients.

Patient (#)	Age (year)	HMGI (ng/ml)	Diagnosis	Outcome
1	27	<d.l.	Normal	Healthy
2	34	<d.l.	Normal	Healthy
3	35	<d.l.	Normal	Healthy
4	36	<d.l.	Normal	Healthy

5	61	<d.l.	Normal	Healthy
6	31	<d.l.	Normal	Healthy
7	55	10	Sepsis, anastomotic leak	Recovered
8	70	7-20	Sepsis, colonic perforation	Recovered
9	44	10-60	Sepsis, MOF, spinal reconstruction	Died
10	60	>120	Sepsis, MOF, perforated gastric ulcer	Died
11	47	>120	Sepsis, MOF, pneumonia	Died

Note: <d.l. - below detection limit; MOF - Multiple Organ Failure.

These data show that elevated serum HMG1 levels are observed in patients with sepsis, and the highest levels of serum HMG1 are observed in lethal cases (Table 2). These data further indicate the therapeutic importance of HMG1 antagonists in sepsis and also provide evidence for the diagnostic utility of an assay for sepsis and severity (*i.e.*, potential lethality) of sepsis by measuring serum concentrations of HMG1. This diagnostic assay is also useful for diagnosing the severity of allied conditions involving activation of the inflammatory cytokine cascade.

Additional subjects were screened for serum HMG1 levels in association with lethal versus non-lethal sepsis, with results (cumulative with Table 2) as described in Figure 6. The data summarized in Figure 6 represent serum samples obtained from eight healthy subjects and twenty-five septic patients infected with Gram positive [*Bacillus fragilis* (1 patient), *Enterococcus faecalis* (1 patient), *Streptococcus pneumonia* (4 patients), *Listeria monocytogenes* (1 patient), or *Staphylococcus aureus* (2 patients)], Gram negative [*Escherichia coli* (7 patients), *Klebsiella pneumonia* (1 patient), *Acinetobacter calcoaceticus* (1 patient), *Pseudomonas aeruginosa* (1 patient), *Fusobacterium nucleatum* (1 patient), *Citrobacter freundii* (1 patient)], or unidentified pathogens (5 patients). Serum was fractionated by SDS-PAGE gel electrophoresis, and HMG1 levels were determined by Western blotting analysis with reference to standard curves of purified rHMG1 diluted in normal human serum. The detection limit by Western blotting analysis is 50 pg. Note that HMG1 is not detectable in normal controls, but significantly increased in septic patients. The average level of HMG1 in serum of non-surviving septic patients (N = 13 patients, mean HMG1 level = 83.7 ± 22.3 ng/ml) is significantly higher than in survivors (N = 12, mean HMG1 level = 25.2 ± 15.1 ng/ml, $P < 0.05$). These data provide direct evidence of the utility of screening tissue (including, without limitation blood or serum) samples for HMG1 sequences (protein or nucleic acid) as a diagnostic and prognostic indicator of the presence of sepsis and related disorders of cytokine activation and of the severity and likely clinical course of such diseases and conditions.

Example 8: HMG1 induces pro-inflammatory mediators and weight loss

The present results provide evidence that HMG1 is a late released mediator element of the inflammatory cytokine cascade. Addition of recombinant HMG1 to primary human peripheral blood mononuclear cells led to the dose-dependent induction of TNF within four

hours after stimulation (Figure 3A). This stimulation by recombinant HMG1 of TNF release by HuPBMCs was not due to LPS contamination because: (i) purified recombinant HMG1 was not contaminated by LPS as judged by an LAL endotoxin assay; ii) addition of the LPS-neutralizing agent polymyxin B did not affect HMG1-induced TNF release; and iii) proteolytic cleavage of recombinant HMG1 preparations with trypsin completely abolished the TNF release activity for the PBMC cultures. HMG1 stimulation also induced macrophages to release nitric oxide (NO).

To confirm that HMG1 induced serum TNF release *in vivo*, purified recombinant HMG1 was administered intraperitoneally to Balb/C mice, and blood samples were collected to be assayed for TNF by the L929 assay. As shown in Figure 3B, TNF was not detectable in serum of control animals, but was significantly increased two hours after administration of recombinant HMG1 protein.

Repetitive administration of recombinant gene product of the HMG1 gene (100 µg/mouse/day) caused significant body weight loss (Figure 4) in mice. Without limitation as to mechanism and without being bound by theory, these data are consistent with the hypothesis that HMG1 acts as a feed-forward stimulator of the pro-inflammatory cascade under both *in vitro* and *in vivo* conditions. These *in vivo* data in a predictive model of weight loss also provide predictive evidence that a pharmaceutical formulation comprising HMG1, or a therapeutically active fragment thereof, is an effective weight loss therapy.

Example 9: *In vivo* sources of HMG1

Serum HMG1 levels in hypophysectomized versus control rats also were measured by quantitation of Western blot intensities as described above. There were significantly higher HMG1 levels within 12 hours after endotoxic challenge (LPS at 1.0 mg/kg) in hypophysectomized rats (approximately 75 ng/ml) as compared to controls (approximately 25 ng/ml). These results indicate that pituitary cells are not the major source of serum HMG1 levels and that macrophages may play a quantitatively more important role.

We claim:

1. A pharmaceutical composition for treating conditions (diseases) characterized by activation of the inflammatory cytokine cascade, comprising an effective amount of an antagonist or inhibitor of HMG1.
- 5 2. A pharmaceutical composition for treating sepsis and related conditions, comprising an effective amount of an HMG1 antagonist.
3. The pharmaceutical composition of claims 1 or 2 wherein the HMG1 antagonist is selected from the group consisting of antibodies that bind to HMG1, HMG1 antisense sequences and HMG1 receptor antagonists.
- 10 4. A method for treating a condition characterized by activation of the inflammatory cytokine cascade, comprising administering an effective amount of an HMG1 antagonist.
5. A method for treating sepsis and related conditions involving activation of the inflammatory cytokine cascade syndrome, comprising administering an effective amount of an
15 HMG1 antagonist.
6. The method of claims 4 or 5 further comprising administering a second agent in combination with the HMG1 antagonist, wherein the second agent is an antagonist of an early sepsis mediator.
7. The methods of claim 6 wherein the second agent is an antagonist of a cytokine
20 selected from the group consisting of TNF, IL-1 α , IL-1 β , MIF and IL-6.
8. The method of claim 7 wherein the second agent is an antibody to TNF or MIF or an IL-1 receptor antagonist (IL-1ra).
7. A diagnostic and prognostic method for monitoring the severity and predicting the likely clinical course of sepsis and related conditions for a patient exhibiting shock-like
25 symptoms or at risk to exhibit symptoms associated with conditions characterized by activation of the inflammatory cascade, comprising measuring the concentration of HMG1 in a sample, and comparing that concentration to a standard for HMG1 representative of a normal concentration range of HMG1 in a like sample, whereby higher levels of HMG1 are indicative of poor prognosis or the likelihood of toxic reactions.
- 30 8. The diagnostic or prognostic method of claim 7 wherein the sample is a serum sample.
9. A diagnostic method for monitoring the diagnosing or monitoring the severity of sepsis or septic shock, comprising measuring a serum concentration of HMG1 in a patient at risk to exhibit or exhibiting sepsis or septic shock-like symptoms, whereby higher levels of
35 HMG1 are indicative of a diagnosis of sepsis or septic shock or a poor prognosis.
10. A pharmaceutical composition for effecting weight loss or treating obesity, comprising an effective amount of HMG1 or a therapeutically active fragment thereof.
11. A method for effecting weight loss or treating obesity, comprising administering an effective amount of HMG1 or a therapeutically active fragment thereof.

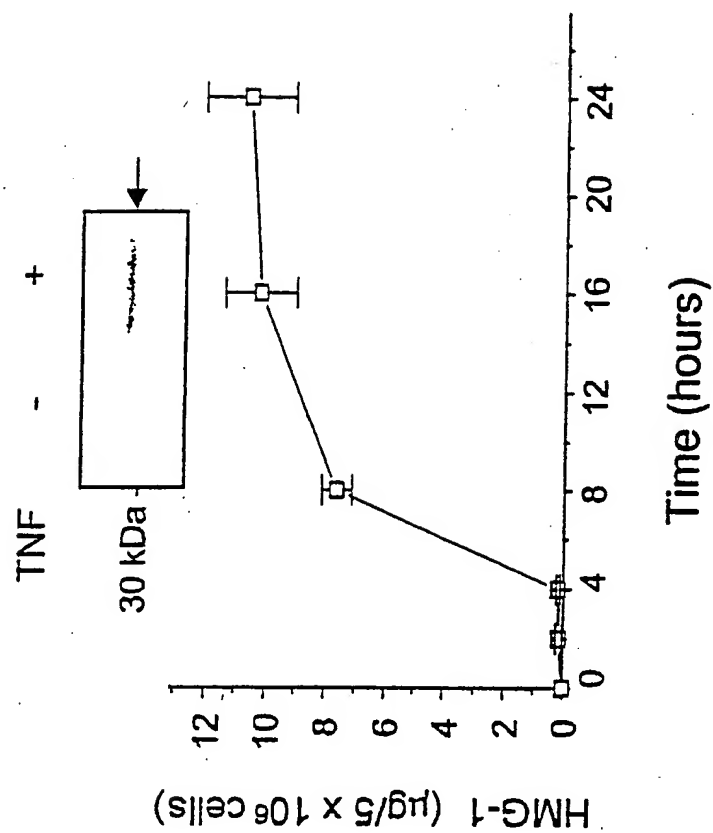


Fig. 1a

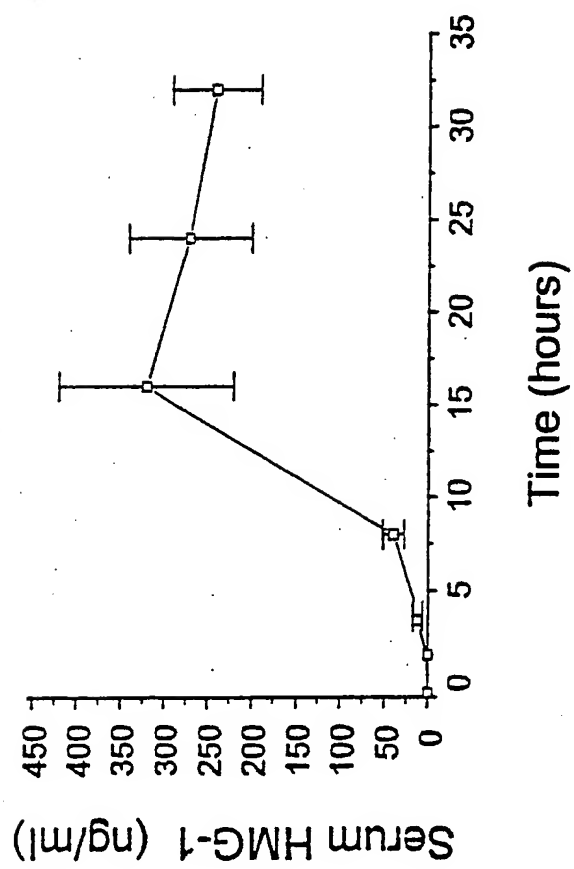


Fig. 1b

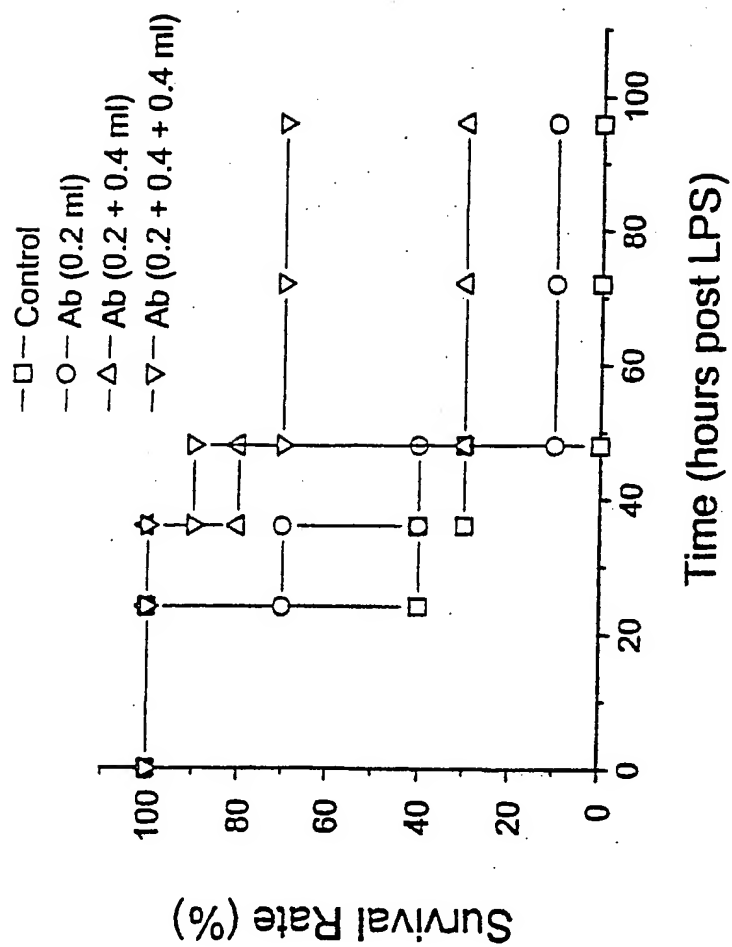


Fig. 2a

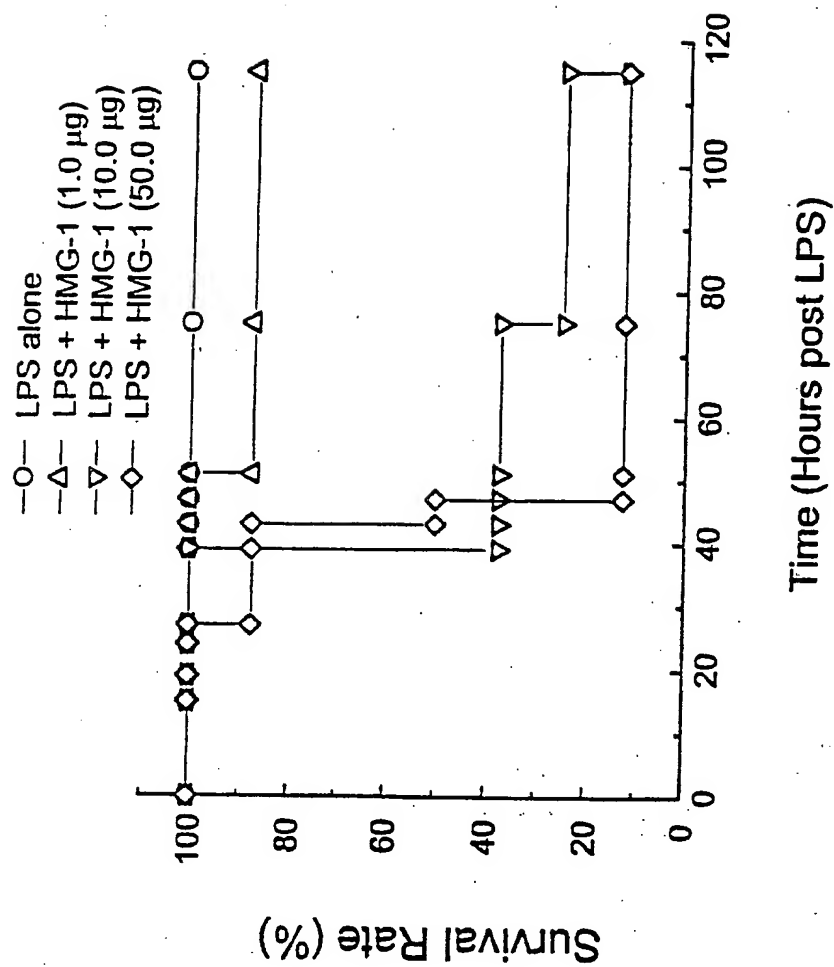


Fig. 2b

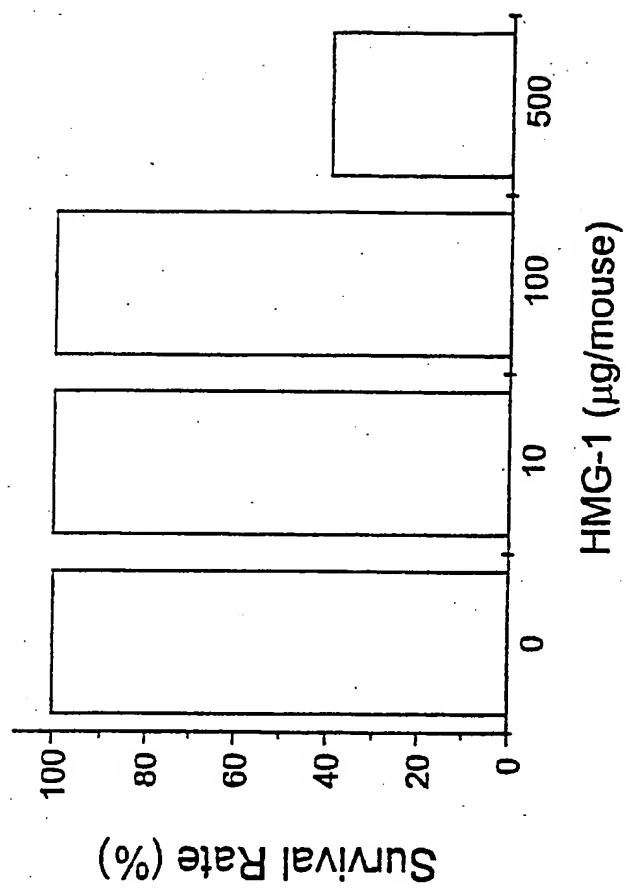


Fig. 2c

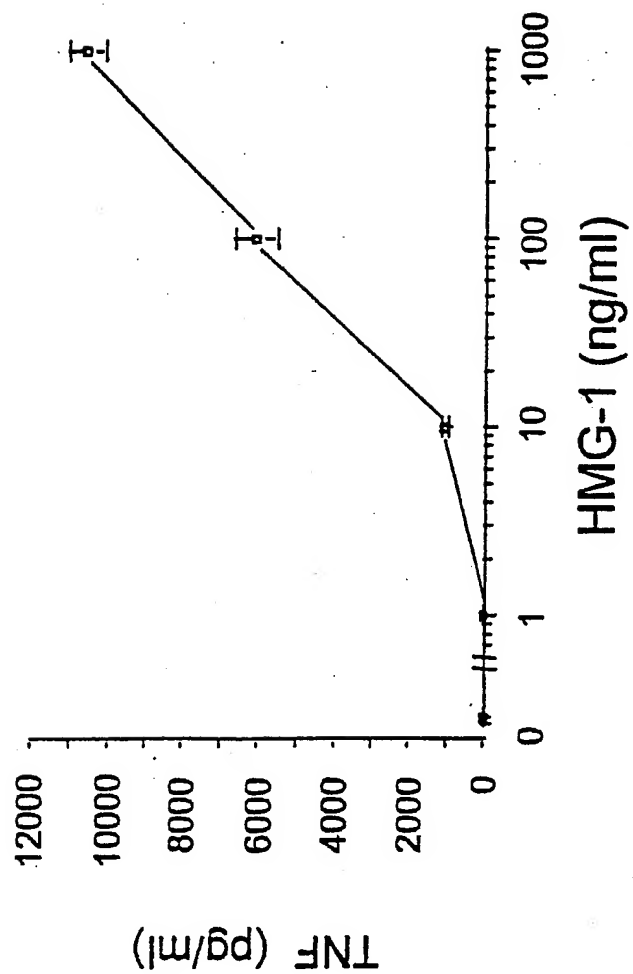


Fig. 3a

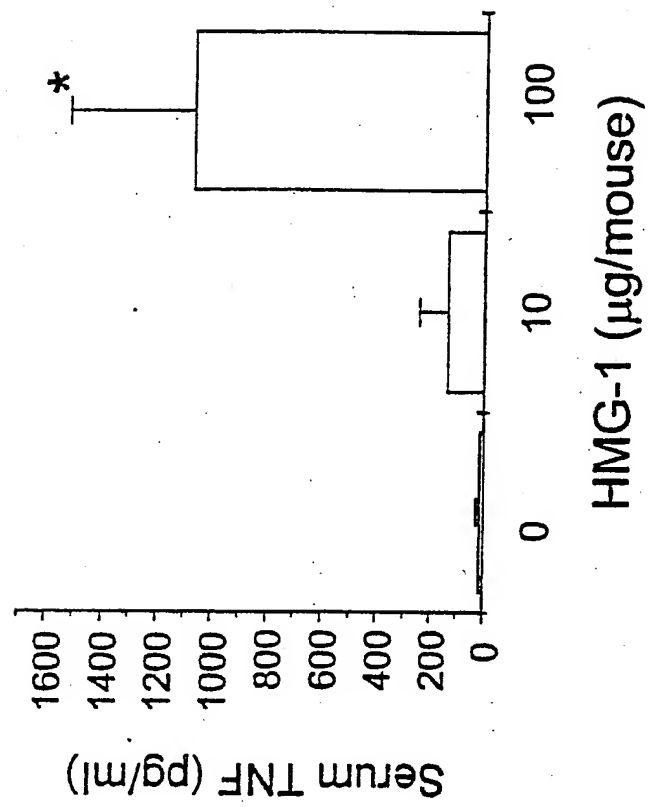


Fig. 3b

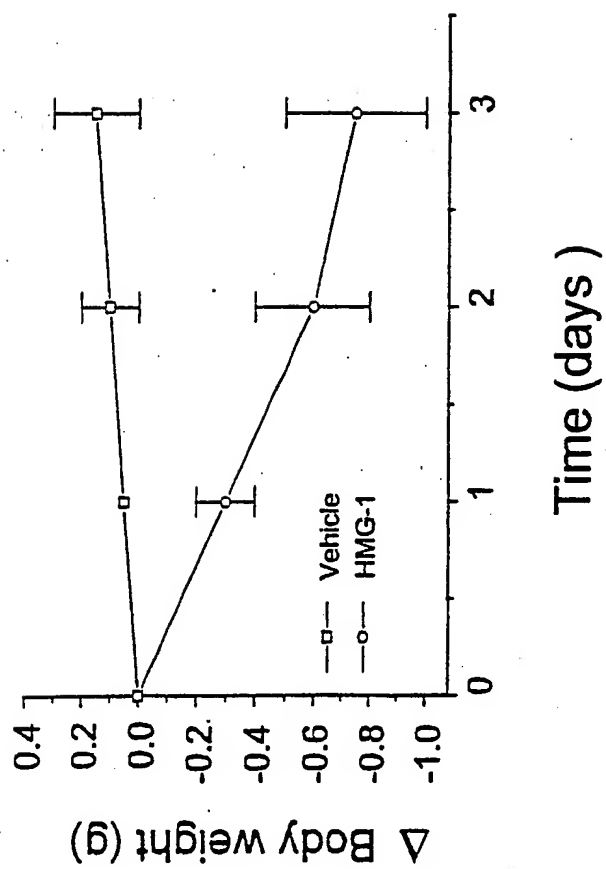


Fig. 4

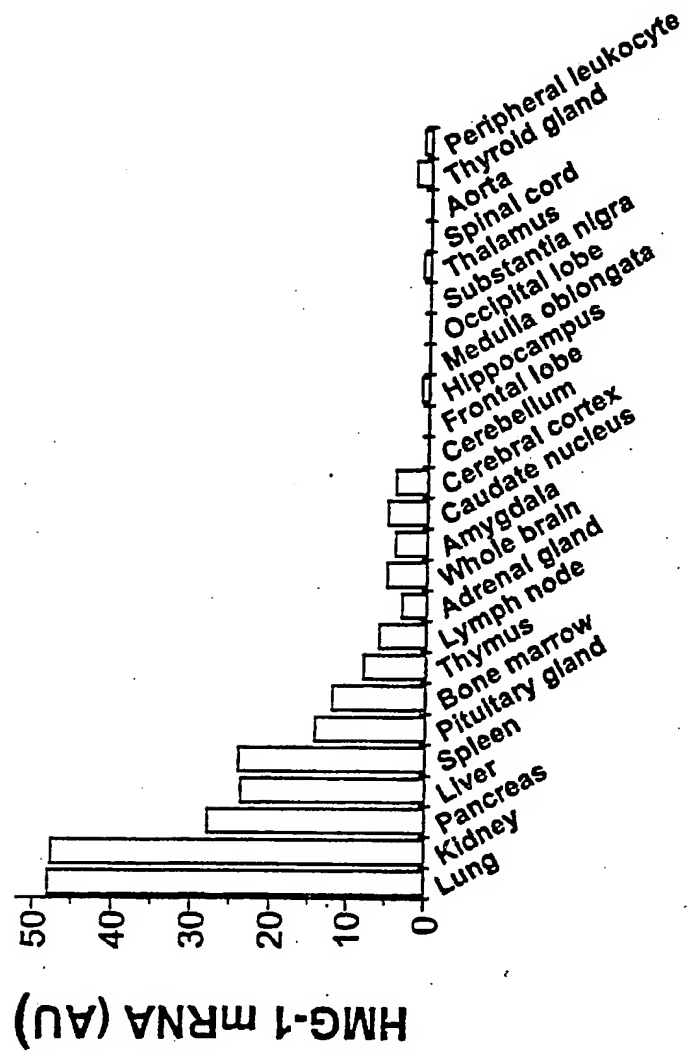


Fig. 5

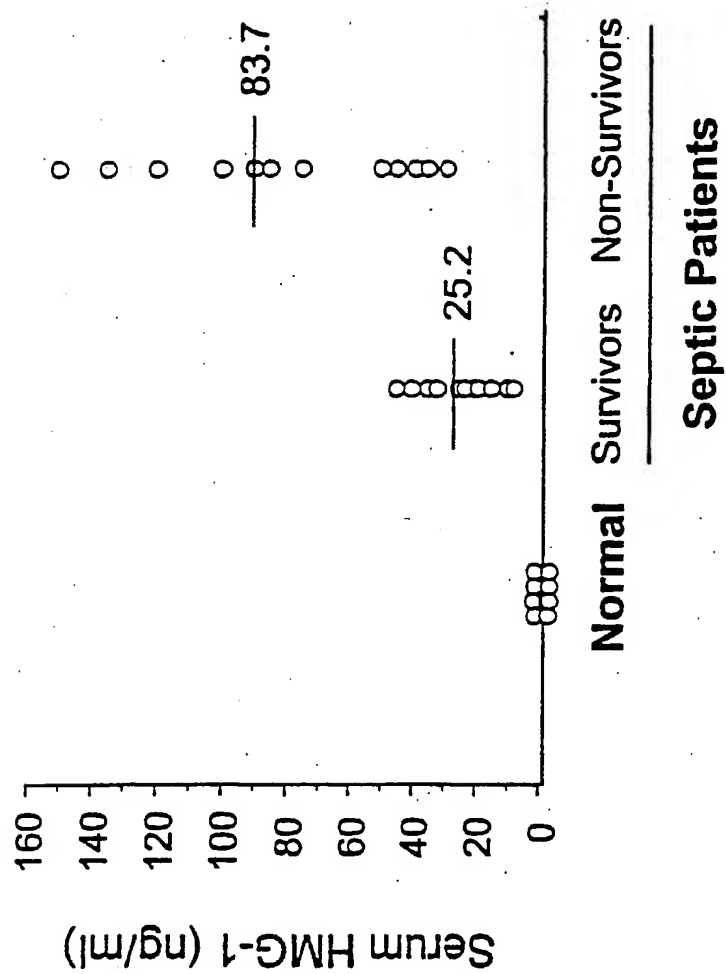


Fig. 6

SEQUENCE LISTING

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(iv) CORRESPONDENCE ADDRESS:
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 (F) ZIP: 98101
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 (B) COMPUTER: PC compatible
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(2) INFORMATION FOR SEQ ID NO:1:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 14
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: unknown
- (ii) MOLECULE TYPE: HMGl N terminal

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

Gly Lys Gly Asp Pro Lys Lys Pro Arg Gly Lys Met Ser Ser 14
5 10

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 42
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: PCR primer

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

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(i) SEQUENCE CHARACTERISTICS:

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- (C) STRANDEDNESS: single
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: PCR Primer

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

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(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

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(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 42
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: HMGl cDNA region spanning initiator sequence

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

GAGGAAAAAT AACTAAACAT GGGCAAAGGA GATCCTAAGA AG 42

CORRECTED VERSION

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(54) Title: ANTAGONISTS OF HMGI FOR TREATING INFLAMMATORY CONDITIONS

(57) Abstract: There is disclosed a pharmaceutical composition and method for treating sepsis, including septic shock and ARDS (acute respiratory distress syndrome), comprising administering an effective amount of an HMGI antagonist. There is further disclosed a diagnostic method for monitoring the severity or potential lethality of sepsis or septic shock, comprising measuring the serum concentration of HMGI in a patient exhibiting or at risk or exhibit sepsis or septic shock symptoms. Lastly, there is disclosed a pharmaceutical composition and method for effecting weight loss or treating obesity, comprising administering an effective amount of HMGI or a therapeutically active HMGI fragment.

ANTAGONISTS OF HMG1 FOR TREATING INFLAMMATORY CONDITIONS

Technical Field of the Invention

The present invention provides a pharmaceutical composition and method for treating
5 diseases characterized by activation of an inflammatory cytokine cascade, particularly sepsis,
including septic shock and ARDS (acute respiratory distress syndrome), comprising
administering an effective amount of an antagonist to the high mobility group 1 protein
(HMG1). The present invention further provides a diagnostic method for monitoring the
severity of sepsis and related conditions, comprising measuring the serum concentration of
10 HMG1 in a patient exhibiting symptoms of a disease characterized by activation of
inflammatory cytokine cascade. Lastly, the present invention provides a pharmaceutical
composition and method for effecting weight loss or treating obesity, comprising administering
an effective amount of an HMG1 protein or a therapeutically active fragment of the gene
product of an HMG1 gene.

15 Background of the Invention

Sepsis is an often fatal clinical syndrome that develops after infection or injury. Sepsis
is the most frequent cause of mortality in hospitalized patients. Experimental models of gram
negative sepsis based on administration of bacterial endotoxin (lipopolysaccharide, LPS) have
led to an improved understanding of the pathogenic mechanisms of lethal sepsis and conditions
20 related to sepsis by virtue of the activation of a common underlying inflammatory cytokine
cascade. This cascade of host-response mediators includes TNF, IL-1, PAF and other
macrophage-derived factors that have been widely studied as acute, early mediators of eventual
lethality in severe endotoxemia (Zhang and Tracey, In *The Cytokine Handbook*, 3rd ed. Ed.
Thompson (Academic Press Limited, USA). 515-547, 1998).

25 Unfortunately, therapeutic approaches based on inhibiting these individual "early"
mediators of endotoxemia have met with only limited success in large prospective clinical
trials against sepsis in human patients. It is possible to infer from these disappointing results
that later-appearing factors in the host response might critically determine pathogenesis and/or
lethality in sepsis and related disorders. Accordingly, there is a need to discover such putative
30 "late" mediators necessary and/or sufficient for part or all of the extensive multisystem
pathogenesis, or for the lethality, of severe endotoxemia, particularly as endotoxemia is
representative of clinical sepsis and related clinical disorders.

HMG1 is a 30 kDa chromosomal nucleoprotein belonging to the burgeoning high
mobility group (HMG) of non-histone chromatin-associated proteins. As a group, the HMG
35 proteins recognize unique DNA structures and have been implicated in diverse cellular
functions, including determination of nucleosome structure and stability, as well as in
transcription and/or replication. The HMG proteins were first characterized by Johns and
Goodwin as chromatin components with a high electrophoretic mobility in polyacrylamide gels
(see in *The HMG Chromosomal Proteins*, E.W. Johns, Academic Press, London, 1982).

Higher eukaryotes exhibit three families of HMG proteins: the HMG-1/-2 family, the HMG-14/-17 family and the HMG-I/-Y family. Although the families are distinguishable by size and DNA-binding properties, they are similar in their physical properties. HMG proteins are highly conserved across species, ubiquitously distributed and highly abundant, and are extractable from chromatin in 0.35 M NaCl and are soluble in 5% perchloric or trichloroacetic acid. Generally, HMG proteins are thought to bend DNA and facilitate binding of various transcription factors to their cognate sequences, including for instance, progesterone receptor, estrogen receptor, HOX proteins, and Oct1, Oct2 and Oct6. Recently, it has become apparent that a large, highly diverse group of proteins including several transcription factors and other DNA-interacting proteins, contain one or more regions similar to HMG1, and this feature has come to be known as the HMG1 box or HMG1 domain. cDNAs coding for HMG1 have been cloned from human, rat, trout, hamster, pig and calf cells, and HMG1 is believed to be abundant in all vertebrate cell nuclei. The protein is highly conserved with interspecies sequence identities in the 80% range. In chromatin, HMG1 binds to linker DNA between nucleosomes and to a variety of non- β -DNA structures such as palindromes, cruciforms and stem-loop structures, as well as cisplatin-modified DNA. DNA binding by HMG1 is generally believed to be sequence insensitive. HMG1 is most frequently prepared from washed nuclei or chromatin, but the protein has also been detected in the cytoplasm. (Reviewed in Landsman and Bustin, *BioEssays* 15:539-546, 1993; Baxevanis and Landsman, *Nucleic Acids Research* 23:514-523, 1995). To date, no link has been established between the HMG proteins and any clinical condition or disease.

HMG1 has been alternatively identified as a heparin-binding protein abundantly expressed in developing brain and dubbed "amphoterin" for its highly dipolar sequence, comprising two internal repeats of a positively charged domain of about 80 amino acids (the HMG1 box) and an acidic C-terminal domain containing a stretch of approximately 30 continuous glutamic or aspartic acid residues. Amphoterin/HMG1 has been localized to the outer surface of the plasma membranes of epithelial, and especially neuronal cells, where it has been specifically localized to the filipodia of neural cells. Inhibition studies have suggested that amphoterin/HMG1 is required for process (neurite) extension and amphoterin/HMG1 also may be involved in neuron-glia interactions (Merenmies et al., *J. Biol. Chem.* 266:16722-16729, 1991; Merenmies et al., *J. Biol. Chem.* 266:16722-16729, 1991; Milev et al., *J. Biol. Chem.* 273:6998-7005, 1998; and Salmivirta et al., *Exp. Cell Res.* 200:444-451, 1992). Amphoterin/HMG1 can be released from murine erythroleukemia cells after stimulation with the chemical inducer hexamethylenebisacetamide (Melloni et al., *Biochem. Biophys. Res. Commun.* 210:82-89, 1995). Previous study suggested that the gene product of the HMG1 gene functions as a differentiation enhancing factor by stimulating α -PKC (Melloni et al., *Biochem. Biophys. Res. Commun.* 210:82-89, 1995; and Melloni et al., *FEBS Lett.* 368:466-470, 1995).

The HMG1 gene product has been shown to interact with plasminogen and tissue-type plasminogen activator (t-PA) and effectively enhance plasmin generation at the cell surface, a system that is known to play a role in extracellular proteolysis during cell invasion and tissue remodeling. Amphoterin/HMG1 has also been shown to interact with the receptor of advanced glycosylation end products (RAGE) (Mohan et al., *Biochem. Biophys. Res. Commun.* 182:689-696, 1992; Yamawaki et al., *J. Neurosci. Res.* 44:586-593, 1996; Salmivirta et al., *Exp. Cell Res.* 200:444-451, 1992; and Vassalli et al., *J. Clin. Invest.* 88:1067-1072, 1991), (Redlitz and Plow, *Baillieres Clin. Haematol.* 8:313-327, 1995; and Parkkinen et al., *J. Biol. Chem.* 266:16730-16735, 1991).

There is a longstanding need in the art to discover improved agents that can prevent the cytokine-mediated inflammatory cascade and have therapeutic activity in a large variety of cytokine-mediated inflammatory diseases. The present invention was made during the course of investigative research to identify agents that mediate toxicity, pathogenesis and/or lethality in sepsis and other disorders related by a common activation of the inflammatory cytokine cascade.

Diseases and conditions mediated by the inflammatory cytokine cascade are numerous. Such conditions include the following grouped in disease categories:

Systemic Inflammatory Response Syndrome, which includes:

Sepsis syndrome

Gram positive sepsis

Gram negative sepsis

Culture negative sepsis

Fungal sepsis

Neutropenic fever

Urosepsis

Meningococcemia

Trauma hemorrhage

Hums

Ionizing radiation exposure

Acute pancreatitis

Adult respiratory distress syndrome (ARDS)

Reperfusion Injury, which includes

Post-pump syndrome

Ischemia-reperfusion injury

Cardiovascular Disease, which includes

Cardiac stun syndrome

Myocardial infarction

Congestive heart failure

Infectious Disease, which includes

- HIV infection/HIV neuropathy
- Meningitis
- Hepatitis
- Septic arthritis
- 5 Peritonitis
- Pneumonia Epiglottitis
- E. coli 0157:H7*
- Hemolytic uremic syndrome/thrombolytic thrombocytopenic purpura
- Malaria
- 10 Dengue hemorrhagic fever
- Leishmaniasis
- Leprosy
- Toxic shock syndrome
- Streptococcal* myositis
- 15 Gas gangrene
- Mycobacterium tuberculosis*
- Mycobacterium avium intracellulare*
- Pneumocystis carinii* pneumonia
- Pelvic inflammatory disease
- 20 Orchitis/epididymitis
- Legionella
- Lyme disease
- Influenza A
- Epstein-Barr Virus
- 25 Viral associated hemaphagocytic syndrome
- Viral encephalitis/aseptic meningitis
- Obstetrics/Gynecology, including:
 - Premature labor
 - Miscarriage
- 30 Infertility
- Inflammatory Disease/Autoimmunity, which includes:
 - Rheumatoid arthritis/seronegative arthropathies
 - Osteoarthritis
 - Inflammatory bowel disease
- 35 Systemic lupus erythematosus
- Iridoeyelitis/uveitistopic neuritis
- Idiopathic pulmonary fibrosis
- Systemic vasculitis/Wegener's granulomatosis
- Sarcoidosis

- Orchitis/vasectomy reversal procedures
- Allergic/Atopic Diseases, which includes:
- Asthma
 - Allergic rhinitis
 - 5 Eczema
 - Allergic contact dermatitis
 - Allergic conjunctivitis
 - Hypersensitivity pneumonitis
- Malignancy, which includes:
- 10 ALL
 - AML
 - CML
 - CLL
 - Hodgkin's disease, non-Hodgkin's lymphoma
 - 15 Kaposi's sarcoma
 - Colorectal carcinoma
 - Nasopharyngeal carcinoma
 - Malignant histiocytosis
 - Paraneoplastic syndrome/hypercalcemia of malignancy
 - 20 Transplants, including:
 - Organ transplant rejection
 - Graft-versus-host disease
 - Cachexia
- Congenital, which includes:
- 25 Cystic fibrosis
 - Familial hematomphagocytic lymphohistiocytosis
 - Sickle cell anemia
- Dermatologic, which includes:
- 30 Psoriasis
 - Alopecia
- Neurologic, which includes:
- Multiple sclerosis
 - Migraine headache
- Renal, which includes:
- 35 Nephrotic syndrome
 - Hemodialysis
 - Uremia
- Toxicity, which includes:
- OKT3 therapy

- Anti-CD3 therapy
- Cytokine therapy
- Chemotherapy
- Radiation therapy
- 5 Chronic salicylate intoxication
- Metabolic/Idiopathic, which includes:
 - Wilson's disease
 - Hemachromatosis
 - Alpha-1 antitrypsin deficiency
 - 10 Diabetes
 - Hashimoto's thyroiditis
 - Osteoporosis
 - Hypothalamic-pituitary-adrenal axis evaluation
 - Primary biliary cirrhosis

15 **Summary of the Invention**

The present invention provides a pharmaceutical composition for treating conditions (diseases) mediated by the inflammatory cytokine cascade, comprising an effective amount of an antagonist or inhibitor of HMG1. Preferably, the HMG1 antagonist is selected from the group consisting of antibodies that bind to an HMG1 protein, HMG1 gene antisense sequences and HMG1 receptor antagonists. The present invention provides a method for treating a condition mediated by the inflammatory cytokine cascade, comprising administering an effective amount of an HMG1 antagonist. In another embodiment, the inventive method further comprises administering a second agent in combination with the HMG1 antagonist, wherein the second agent is an antagonist of an early sepsis mediator, such as TNF, IL-1 α , IL-1 β , MIF or IL-6. Most preferably, the second agent is an antibody to TNF or an IL-1 receptor antagonist (IL-1ra).

The present invention further provides a diagnostic and prognostic method for monitoring the severity and predicting the likely clinical course of sepsis and related conditions for a patient exhibiting shock-like symptoms or at risk to exhibit symptoms associated with conditions mediated by the inflammatory cascade. The inventive diagnostic and prognostic method comprises measuring the concentration of HMG1 in a sample, preferably a serum sample, and comparing that concentration to a standard for HMG1 representative of a normal concentration range of HMG1 in a like sample, whereby higher levels of HMG1 are indicative of poor prognosis or the likelihood of toxic reactions. The diagnostic method may also be applied to other tissue or fluid compartments such as cerebrospinal fluid or urine. Lastly, the present invention provides a pharmaceutical composition and method for effecting weight loss or treating obesity, comprising administering an effective amount of HMG1 or a therapeutically active fragment thereof.

Brief Description of the Drawings

Figure 1 shows two graphs that profile the induction of HMGI release by LPS *in vitro* (Figure 1A) and *in vivo* (Figure 1B). Specifically, Figure 1A shows the accumulation of HMGI in culture supernatants of macrophage RAW 264.7 cells after stimulation with LPS (100 ng/ml). The inset is a Western blot (using antibodies raised against recombinant HMGI) showing induction of HMGI release from RAW 264.7 cells after induction with TNF. Figure 1B shows accumulation of HMGI in serum of LPS-treated mice. Serum from Balb/C mice was collected at various time points after LPS administration, and assayed for HMGI by Western blotting using antibodies raised against recombinant HMGI.

Figure 2 illustrates that HMGI is a mediator of pathogenesis and lethality in endotoxemia. Figure 2A shows the protective effect of anti-HMGI antibodies against LPS lethality, tested in mice. Administration of anti-HMGI antiserum in the indicated amounts at -0.5 (if one dose), -0.5 and 12 (if two doses), or -0.5, 12 and 36 (if three doses) hours relative to LPS challenge (at time 0) was protective against LPS-induced lethality, and repeated dosing schedules provided better protection. Figure 2B illustrates that rHMGI caused dose-dependent lethality in endotoxic mice. Male Balb/C mice (20-23 grams) were randomized in groups of ten to receive LPS (3.15 mg/kg; a non-lethal dose) alone or in combination with purified recombinant HMGI protein. Administration of HMGI at the indicated doses 2, 16, 28 and 40 hours after LPS challenge significantly increased the lethality of the underlying endotoxemia. Figure 2C illustrates independent lethal toxicity of HMGI as a function of dose. Purified rHMGI was administered to male Balb/C mice (five mice per treatment group) as a single i.p. bolus at the indicated dosage. Mice were observed for at least 48 hours, and 60% of mice treated with rHMGI at a dose of 500 µg/mouse died within 24 hours of rHMGI challenge, indicating a single dose LD₅₀ of less than 500 µg/mouse.

Figure 3 shows that HMGI induced TNF release both *in vitro* (Figure 3A) and *in vivo* (Figure 3B). Specifically, Figure 3A shows that HMGI induces TNF release from huPPBMCs in dose-dependent fashion. Freshly isolated huPBMC cultures were stimulated with purified recombinant HMGI protein at the indicated doses, and culture media were sampled four hours later to be assayed for TNF according to known immunologic methods (ELISA). Figure 3A shows the mean ± S.E.M. of the induced TNF response in two experiments (in triplicate). Figure 3B shows that administration of HMGI induced accumulation of TNF in serum of treated mice. Balb/C mice (20-23 g) were treated intraperitoneally with purified recombinant HMGI at the indicated doses and blood samples were taken two hours later for assay of TNF by an L929 bioassay and (TNF levels expressed as mean ± S.E.M., N=3).

Figure 4 shows that HMGI caused body weight loss in mice. Purified HMGI was administered intraperitoneally to mice at 100 µg/mouse/day for three days, and body weight was monitored. Figure 4 shows the mean ± S.E.M. of net body weight change of three mice per group.

Figure 5 shows the tissue distribution of HMGI mRNA. Human RNA master blots containing poly(A)⁺ RNA of various tissues (Clontech, Palo Alto, CA, USA) were hybridized

with a 0.6 kb digoxigenin-11-dUTP-labeled HMG1 cDNA probe synthesized by PCR using recombinant plasmid containing the HMG1 cDNA insert, all in accordance with methods well-known in the art. Briefly, hybridization was performed in a hybridization buffer (5X SSC/2% blocking reagent/0.1% SDS/50% formamide, Boehringer Mannheim, Indianapolis, IN) with a probe concentration of 10 ng/ml for 16 hours at 65 °C. After hybridization, the filter was subjected to two washes of 0.5X SSC/0.1% SDS for 5 minutes, and two washes of 0.2X SSC/0.1% SDS for 10 minutes at room temperature. Signal was detected using anti-digoxigenin antibodies conjugated to phosphatase and detection reagents 4-nitrobluetetrazolium chloride (NBT) and 5-cromo-4-chloro-3-indolyl-phosphate (BCIP) (Boehringer-Mannheim) according to standard methods. The blots were scanned with a silver image scanner (SilverScanner II, Lacie Limited, Beaverton, OR), and relative optical density (in arbitrary units, AU) was quantified using NIH 1.59 image software. Note that highest levels were observed in macrophage-rich tissues.

Figure 6 shows, in comparison to a group of normal control subjects, increased human serum HMG1 levels as detected in hospitalized human subjects with sepsis, wherein the septic patients have been further categorized as to whether the patient died or survived.

Detailed Description of the Invention

The present invention is based upon the discovery and isolation of a highly inducible 30 kDa protein that is released by, and accumulates in media conditioned by, cultured murine macrophage-like cells (RAW 264.7) following stimulation with LPS, TNF, or IL-1. A partial amino acid sequence of this isolated polypeptide was identical to the sequence of the HMG1 protein, also known as amphoterin, a protein not before linked to the pathogenesis of any disease. This information was used to clone a cDNA encoding HMG1, which sequence was expressed to provide recombinant protein, which protein was used to generate specific anti-HMG1 antibodies.

Therapeutic and diagnostic efficacy was determined in a series of predictive *in vitro* and *in vivo* experiments. The experiments are detailed in the Examples section. For example, following administration of endotoxin (LD₁₀₀) to mice, serum HMG1 levels increased later (at 16 h) than well-known "early" mediators of sepsis (such as TNF and IL-1) and plateau levels of HMG1 were maintained for 16 to 32 hours. Patients with lethal sepsis had high serum HMG1 levels, which were not detected in normal healthy volunteers. Moreover, acute experimental administration of rHMG1 to test animals, whether alone or in combination with sub-lethal amounts of LPS, caused marked pathological responses and even death. More distributed dosing schedules of lower amounts of rHMG1 led to significant weight loss in treated animals. These results give evidence that HMG1 is a mediator of endotoxemia and particularly a late mediator, as opposed to known "early" mediators such as TNF and IL-1. These data further show the importance of serum HMG1 as a marker for the severity or potential lethality of sepsis and related conditions.

In addition, treatment with anti-HMG1 antibodies provided full protection from LD₁₀₀ doses of LPS in mice. HMG1 is inducible by TNF and IL-1 β , and dose-dependently stimulates TNF release from huPBMCs. TNF is a marker of macrophage activation, so it is likely (without limitation as to implied mechanisms or being bound by theory) that HMG1 promotes downstream re-activation of cytokine cascades which, in turn, mediates late pathogenesis and lethality in sepsis and related conditions involving activation of pro-inflammatory cytokine responses. Thus, HMG1 likely occupies a central role in mediating the inflammatory response to infection and injury, and antagonists of HMG1 will be of therapeutic benefit in sepsis and related conditions of inflammatory cascade activation. The appearance of HMG1 in the inflammatory cytokine cascade is suitable to propagate later phases of the host response and contribute to toxicity and lethality. The predictive data provided herein support the therapeutic efficacy of HMG1 antagonists and provide evidence in support of the aforementioned theory regarding mechanism of action. The *in vivo* treatment data showed the efficacy of HMG1 antagonists in general, and anti-HMG1 antibodies in particular, for treating conditions mediated by the inflammatory cytokine cascade in general and particularly sepsis conditions, including, for example, septic shock, sepsis syndrome or other "sepsis-like" conditions mediated by inflammatory cytokines. Further, the independent pathogenicity and toxicity/lethality of HMG1 shows that HMG1 antagonists are particularly effective when co-administered with antagonists of "early" inflammatory mediators such as TNF, MIF, IL-1 and IL-6.

In summary, HMG1 is a cytokine mediator of inflammatory reactions because: 1) HMG1 is released from macrophages and pituicytes following stimulation with bacterial toxins or with pro-inflammatory cytokines (TNF or IL-1 β); 2) HMG1 accumulates in serum of animals exposed to LPS and in patients with sepsis; and 3) HMG1-specific antibodies protect against mortality in a predictive lethal endotoxemia animal model of clinical sepsis and related conditions.

Pharmaceutical Composition and Method of Administration

The inventive pharmaceutical composition or inventive pharmaceutical combination can be administered to a patient either by itself (complex or combination) or in pharmaceutical compositions where it is mixed with suitable carriers and excipients. The inventive pharmaceutical composition or inventive pharmaceutical combination can be administered parenterally, such as by intravenous injection or infusion, intraperitoneal injection, subcutaneous injection, or intramuscular injection. The inventive pharmaceutical composition or inventive pharmaceutical combination can be administered orally or rectally through appropriate formulation with carriers and excipients to form tablets, pills, capsules, liquids, gels, syrups, slurries, suspensions and the like. The inventive pharmaceutical composition or inventive pharmaceutical combination can be administered topically, such as by skin patch, to achieve consistent systemic levels of active agent. The inventive pharmaceutical composition or inventive pharmaceutical combination can be formulated into topical creams, skin or

mucosal patches, liquids or gels suitable for topical application to skin or mucosal membrane surfaces. The inventive pharmaceutical composition or inventive pharmaceutical combination can be administered by inhaler to the respiratory tract for local or systemic treatment.

The dosage of the inventive pharmaceutical composition or inventive pharmaceutical combination of the present invention can be determined by those skilled in the art from this disclosure. The pharmaceutical composition or inventive pharmaceutical combination will contain an effective dosage (depending upon the route of administration and pharmacokinetics of the active agent) of the inventive pharmaceutical composition or inventive pharmaceutical combination and suitable pharmaceutical carriers and excipients, which are suitable for the particular route of administration of the formulation (*i.e.*, oral, parenteral, topical or by inhalation). The active agent is mixed into the pharmaceutical formulation by means of mixing, dissolving, granulating, dragee-making, emulsifying, encapsulating, entrapping or lyophilizing processes. The pharmaceutical formulations for parenteral administration include aqueous solutions of the active agent or combination in water-soluble form. Additionally, suspensions of the active agent may be prepared as oily injection suspensions. Suitable lipophilic solvents or vehicles include fatty oils such as sesame oil, or synthetic fatty acid esters, such as ethyl oleate or triglycerides, or liposomes. Aqueous injection suspensions may contain substances that increase the viscosity of the suspension, such as sodium carboxymethyl cellulose, sorbitol, or dextran. The suspension may optionally contain stabilizers or agents to increase the solubility of the active agent or combination to allow for more concentrated solutions.

Pharmaceutical formulations for oral administration can be obtained by combining the active agent with solid excipients, such as sugars (*e.g.*, lactose, sucrose, mannitol or sorbitol), cellulose preparations (*e.g.*, starch, methyl cellulose, hydroxypropylmethyl cellulose, and sodium carboxymethyl cellulose), gelatin, gums, or polyvinylpyrrolidone. In addition, a disintegrating agent may be added, and a stabilizer may be added.

Antisense Oligomers

The present invention provides antisense oligomers having a sequence effective to inhibit or block the expression of the HMG1 gene or mRNA sequence. Antisense technology, which uses specific- oligonucleotides to inhibit expression of target gene products, is developing as a therapeutic modality for human disease. Several selection criteria are available to contribute to the optimization of antisense oligonucleotide antagonists. For example, it is advisable to choose sequences with 50% or more GC content. Preferred sequences span the AUG initiation codon of the target protein, but sites in the coding region and 5' UTR may perform equally well. Such sequences are generally about 18-30 nucleotides long and chosen to overlap the ATG initiation codon from the HMG1 cDNA sequence to inhibit protein expression. Longer oligomers are often found to inhibit the target to a greater extent, indicating that a preferred length is about 25 mer for the first oligonucleotides chosen as antisense reagents. Typically, three oligonucleotide sequences are chosen with regard to these

criteria, and compared for antagonist activity to control oligonucleotide sequences, such as "reverse" oligonucleotides or those in which about every fourth base of the antisense sequence is randomized. Therefore, a preferred sequence for making antisense oligomer sequences to HMG1 is a 25 mer sequence chosen to overlap the ATG initiation codon (underlined) from the

5 HMG1 cDNA sequence:

GAGGAAAAATAACTAAACATGGGCAAAGGAGATCCTAAGAAG [SEQ ID NO. 5]

and such preferred antisense sequences are used to construct antisense oligonucleotide agents (and suitable controls) for an *in vitro* comparison as antagonists of HMG1. These *in vitro* data are predictive of human clinical utility using antisense agents of comparable design.

10 HMG1-directed Antibodies

The antibodies disclosed herein may be polyclonal or monoclonal; may be from any of a number of human, non-human eukaryotic, cellular, fungal or bacterial sources. The antibodies may be encoded by genomic or vector-borne coding sequences, and may be elicited against native or recombinant HMG1 or fragments thereof with or without the use of

15 adjuvants. The methods for making antibodies are methods and procedures well-known in the art for generating and producing antibodies. Generally, neutralizing antibodies against HMG1 (*i.e.*, those that inhibit biological activities of HMG1 particularly with regard to its pro-inflammatory cytokine-like role) are preferred for therapeutic applications while non-neutralizing antibodies may be as suitable for diagnostic applications. Examples of such useful

20 antibodies include but are not limited to polyclonal, monoclonal, chimeric, single-chain, and various human or humanized types of antibodies, as well as various fragments thereof such as Fab fragments and fragments produced from specialized expression systems.

Diagnostic Assay

The diagnostic assay provided here uses anti-HMG1 antibodies that can be either

25 polyclonal or monoclonal or both. The diagnostic procedure can utilize standard antibody-based techniques for measuring concentrations of the gene product of HMG1 genes in a biological fluid. Preferred standard diagnostic procedures are ELISA assays and Western techniques.

Example 1: Identification of HMG1 as a "late" mediator of endotoxemia

30 This example provides the results of an experiment to identify and isolate later released macrophage-derived factors that play a role in sepsis and in related conditions typified by inflammatory cytokine activity. The experiment reported in this example examined murine macrophage RAW 264.7 cell-conditioned media after stimulation of the cultures with TNF. Murine macrophage RAW 264.7 cells were obtained from American Type Culture Collections

35 (ATCC, Rockville, MD, USA), and proliferated in culture under DMEM supplemented with 10% fetal bovine serum and 1% glutamine. When confluency reached 70-80%, the medium was replaced by serum-free OPTI-MEM I medium and cultures were stimulated with pro-inflammatory cytokines (*e.g.*, TNF α or IL-1) or bacterial endotoxin (LPS).

The proteins released from the above stimulated macrophage cultures were surveyed. Specifically, at different time points, cells and cell-conditioned media were separately collected by centrifugation (3000 rpm, 10 minutes). Proteins in the conditioned medium were concentrated by ultrafiltration over Amicon membranes with Mr cutoff of 10 kDa (Amicon Inc., Beverly, MA, USA), subsequently fractionated by SDS-PAGE, and stained with Coomassie blue (1.25% Coomassie Blue R250 in 30% methanol/10% acetic acid). After destaining with 30% methanol/7% acetic acid, protein(s) of interest (*i.e.*, those that preferentially accumulated in conditioned media of stimulated cultures) was isolated by excision from the SDS-PAGE gel, and subjected to N-terminal sequencing analysis (Commonwealth Biotechnologies, Inc., Richmond, VA, USA).

Comparison of SDS-PAGE gel analysis of profiles of proteins accumulated in control (without TNF α stimulation) versus TNF-stimulated RAW 264.7 cells revealed a strongly inducible 30 kDa protein whose concentration in the cell-conditioned medium was significantly increased after stimulation for 16 hours. Amino acid sequence analysis of this isolated protein revealed its N-terminal sequence as Gly-Lys-Gly-Asp-Pro-Lys-Lys-Pro-Arg-Gly-Lys-Met-Ser-Ser [SEQ ID NO. 1]. A review of relevant gene databases found a 100% identity to the N-terminal amino acid sequence of HMG1.

These data identified HMG1 as a "late-appearing" product of LPS-stimulated macrophage cultures, and therefore as a candidate pro-inflammatory mediator. This activity was confirmed by administration of recombinantly produced HMG1 and/or of anti-HMG1 antibodies in cellular and animal model systems that are predictive of human clinical conditions.

Example 2: Cellular sources of HMG1

This example shows which cell sources are capable of releasing HMG1 in response to TNF, IL-1 and/or LPS. Cells studied include GH₃ pituitary cells, murine macrophage RAW 264.7 cells, human primary peripheral blood mononuclear cells (huPBMCs), human primary T cells, rat adrenal PC-12 cells, and rat primary kidney cells (Table 1). The rat pituitary GH₃ cell line was obtained from American Type Culture Collection (ATCC, Rockville, MD, USA), and cultured in DME supplemented with 10% fetal bovine serum and 1% glutamine. Human PBMCs and T cells were freshly isolated from whole blood of healthy donors and cultured in RPMI 1640 supplemented with 10% human serum as previously described (Zhang et al., *J. Exp. Med.* 185:1759-1768, 1997). When confluency reached 70-80%, the medium was replaced by serum-free OPTI-MEM I medium and cultures stimulated with proinflammatory cytokines (*e.g.*, TNF α or IL-1) or bacterial endotoxin (LPS).

Although human T cell, rat adrenal (PC-12) cells, and rat primary kidney cells contained cell-associated HMG1 as demonstrated by Western blotting analysis of whole cell lysates using HMG1-specific antibodies (see example 4 below), HMG1 did not significantly accumulate in the medium of these cultures after stimulation with either TNF, IL-1 β , or LPS (Table 1).

Table 1. Induced release of HMGI from various types of cells.

Cell Type	Stimulus		
	TNF	IL-1 β	LPS
Murine RAW 264.7 cells	Yes	Yes	Yes
Human PBMCs	Yes	Yes	Yes
Human primary T cells	No	No	No
Rat adrenal PC-12 cells	No	No	No
Rat pituitary GH ₃ cells	Yes	Yes	No
Rat primary kidney cells	No	No	No

Note: PBMCs, peripheral blood mononuclear cells.

TNF, IL-1 β (minimal effective concentration = 5 ng/ml for each) and bacterial endotoxin (LPS, minimal effective concentration = 10 ng/ml) induced the release of HMGI from human PBMCs in a time- and dose-dependent manner (Table 1). IFN- γ alone (0-200 U/ml) did not induce HMGI release from any of the above cells, but when added in combination either with TNF or IL-1 β , IFN- γ dose-dependently enhanced HMGI release from macrophages, with a maximal 3-fold enhancement by IFN- γ at a concentration of 100 U/ml. The release of HMGI was not due to cell death, because cell viability was unaffected by TNF, IL-1 β , or LPS, as judged by trypan blue exclusion (90-92 \pm 5% viable for control vs. 88-95 \pm 4% in the presence of 100 ng/ml TNF, IL-1 β or LPS). The amount of HMGI released by pituicytes and macrophages inversely correlated with the intracellular concentration of HMGI, as determined by Western blotting analysis, indicating that the released material is, in part, derived from pre-formed cell-associated HMGI protein.

Potential sources of circulating HMGI *in vivo* were assessed by hybridization of an HMGI-specific probe to mRNA prepared from various normal human tissues (blot substrate available from commercial sources), with the results summarized in Figure 5. Several macrophage-rich tissues (lung, liver, kidney, pancreas and spleen) exhibited the most abundant HMGI mRNA expression; less was observed in pituitary, bone marrow, thymus, lymph node and adrenal gland. In addition to providing information as to the relative tissue distribution of HMGI expression, this study shows the practicality and utility of assaying for HMGI-specific nucleic acid sequences in tissue samples.

Example 3: Recombinant HMGI Administration, *in vitro* and *in vivo*

This example details procedures to produce HMGI by well-known recombinant DNA technologies. The HMGI open reading frame was amplified by PCR and subcloned into an expression vector (pCAL-n). Briefly, the 648-bp open reading frame of HMGI cDNA was PCR amplified (94 $^{\circ}$ C 1', 56 $^{\circ}$ C 2', 72 $^{\circ}$ C 45", 30 cycles) from 5 ng Rat Brain Quick-Clone cDNA (Catalog # 7150-1, Clontech, Palo Alto, CA, USA) using primers containing the following sequences, 5'- CCC GCG GAT CCA TCG AGG GAA GGA TGG GCA AAG GAG ATC CTA -3' [SEQ ID NO. 2], and 5'- CCC GCA AGC TTA TTC ATC ATC ATC ATC TTC

T -3' [SEQ ID NO. 3]. The 680 bp PCR product (4 µg) was digested with *Bam* HI and *Hind* III, and cloned into the *Bam* HI/*Hind* III cloning sites of the pCAL-n vector (Stratagene, La Jolla, CA, USA). The recombinant plasmid was transformed into *E. coli* BL21(DE3)pLysS (Novagen, Madison, WI, USA), and positive clones were screened and confirmed by DNA sequencing on both strands using a Tag DyeDeoxy terminator cycle sequencing kit on the ABI 373A automated fluorescent sequencer (Applied Biosystems, Foster City, CA, USA).

To express recombinant HMG1, positive clones were cultured at 37 °C with vigorous shaking (250 rpm) until OD₆₀₀ reached 0.6, when IPTG (1 mM) was added. Twelve hours after IPTG induction, bacterial cells were harvested by centrifugation (6500 rpm, 15 minutes), and lysed by freeze-thaw cycles. The water-soluble fraction was collected after centrifugation (30 minutes, 12,000 rpm), and recombinant HMG1 was purified on a calmodulin-binding resin column as instructed by the manufacturer (Stratagene). Bacterial endotoxin was removed from the recombinant HMG1 by using Detoxi-Gel endotoxin-removing gel (Pierce, Rockford, IL USA, Cat. #20344), and residual LPS content was determined by the Limulus Amebocyte Lysate Test (LAL test, Cat. # 50-648U, QCL-1000 Chromogenic LAL, Bio-Whittaker, Inc., Walkersville, MD, USA). Purified recombinant HMG1 was added to cultures of human peripheral blood mononuclear cells (HuPBMCs), and supernatants assayed for TNF by ELISA four hours after stimulation. The LPS-neutralizing agent polymyxin B (10 µg/ml) was added concurrently with recombinant HMG1 to eliminate the effect of any contaminating LPS on TNF release. Additionally, recombinantly derived HMG1 was administered to test animals, with or without the additional endotoxemic challenge of exogenous LPS, to study the pathogenic potential of high levels of HMG1 *in vivo* (see Figures 2B and 2C). In some experiments, serum samples were secured from HMG1-treated animals to be assayed for TNF as detailed herein (see Figure 1B).

The above procedure provides recombinant HMG1 as a fusion peptide comprising a 3.0 kDa calmodulin-binding domain and a thrombin cleavage site as an amino terminal extension in register with the HMG1 peptide sequence. In some experiments, the fusion tag was removed from an aliquot of the recombinant protein and the bioactivity of the full fusion protein was compared to the cleaved HMG1 peptide; no significant difference in bioactivity was noted and additional experiments (especially those requiring administration of recombinantly produced HMG1 to animals) typically were conducted with the (uncleaved) fusion protein.

As demonstrated in Figures 3A and 3B, *in vitro* or *in vivo* administration of recombinantly derived HMG1 induced a brisk TNF response, confirming the identification of HMG1 as a late-appearing LPS-induced macrophage-derived endogenous mediator with pro-inflammatory activity.

Example 4: Anti-HMG1 antibodies and immunodetection

This example provides the results of experiments to generate and use polyclonal antibodies against HMG1. Briefly, polyclonal antibodies against an oligopeptide

corresponding to the N-terminal amino acid sequence of HMG1, or against purified recombinant HMG1, were generated in rabbits according to standard procedures well known in the art. Briefly, eight copies of an oligopeptide with the sequence GKGDPPKKPRGKMSSC [SEQ ID NO. 4] were anchored to radially branching lysine dendrites (small immunogenically inert core). These large macromolecules were injected three times both subcutaneously and intradermally (0.5 -1.0 mg per injection) into rabbits at week 1, 2, and 4 after pre-bleed at Day 0. Two weeks after the last immunization, rabbits were bled and boosted intramuscularly with 1.0 mg of antigen, followed by a second bleeding two weeks later. Alternatively, to produce polyclonal antibodies against recombinant HMG1, rabbits were immunized with recombinant HMG1 fusion peptide (100 µg per injection) following a similar protocol. Monoclonal antibodies reactive against HMG1 (*i.e.*, that bind, and in some cases, neutralize or antagonize the biological activity of HMG1) are conveniently prepared according to methods well known in the art using the HMG1 antigens described herein or other HMG1 peptide fragments as immunogens. Such monoclonal antibodies, and/or the hybridomas that produce them, are useful to produce various "humanized" antibodies reactive against HMG1 (all according to methods known in the art), which humanized antibodies are useful as taught herein.

HMG1-specific antibodies were used to measure by Western blotting analysis the inducible release of HMG1 from RAW 264.7 cells after treatment with TNF or LPS (Figure 1). Briefly, proteins were fractionated by SDS-PAGE on a 4-20% gradient gel, transferred to a PVDF membrane, and blotted with rabbit antiserum raised against either the N-terminal synthetic HMG1 antigen or against recombinant HMG1. The signal was detected using a ECL kit as instructed by the manufacturer (Amersham Life Science Inc., Arlington Heights, IL, USA), and levels of HMG1 were determined by measuring optical intensity of bands on Western blots digitized for analysis using NIH 1.59 image software, with reference to a standard curve of purified recombinant HMG1.

No HMG1 protein was detected in RAW 264.7 cells-conditioned medium in the absence of TNF or LPS treatment, but HMG1 accumulated in conditioned medium to high levels after such stimulation, reaching a plateau at 8-28 hours after stimulation (Figure 1A). In summary, the data presented in Examples 1, 3 and in Figure 1A show that the release of HMG1 from macrophages is stimulus-specific and time- and dose-dependent, with maximal accumulation observed within 8 hours after stimulation with TNF at concentrations as low as 5 ng/ml. It is well appreciated that sepsis, septic shock and related conditions may occur in humans in response to stimuli that differ qualitatively or quantitatively from the single large, lethal LPS bolus used in this predictive model. Nevertheless, experimental endotoxemia has been a valuable and predictive model system by which to identify critical components of the inflammatory cytokine cascade and by which to identify specific antagonists with predicted clinical utility. In this regard, HMG1 antagonists are perhaps more therapeutically attractive than TNF antagonists in view of the later appearance of HMG1 versus TNF in the response to endotoxin.

Example 5: Detection of HMG1 in *in vivo* animal models

This example illustrates an *in vivo* experiment in rodents measuring serum HMG1 levels after administration of a sublethal dose of LPS (LD₅₀). Mice or rats were treated with LPS, and sera were collected at different time points, and assayed for levels of HMG1 by Western blotting analysis. The serum concentrations of HMG1 were estimated by measuring the optical band intensity with reference to a standard curve of purified HMG1. Serum levels increased significantly by 16 hours after LPS, and remained high for at least 32 hours (Figure 1B), and were not detectable in vehicle-treated control animals. These data show that HMG1 represents a particularly attractive target for diagnosis of, and pharmaceutical intervention against, sepsis and related disorders of cytokine toxicity because HMG1 is a late-appearing mediator in the inflammatory cytokine cascade.

Example 6: Benefits of protection against HMG1

This example provides the results of a predictive *in vivo* assay to measure therapeutic activity of antagonists of HMG1 in relation to treatment of sepsis and related conditions of cytokine-mediated toxicity. In this example, the HMG1 antagonist was an anti-HMG1 antibody preparation. Controls treated with pre-immune serum developed lethargy, piloerection, diarrhea, and succumbed to death within 48 hours. These clinical signs of endotoxemia were significantly prevented by administration of anti-HMG1 antibodies. Male Balb/C mice (6-7 weeks, 20-23 grams) were randomly grouped (10 animals per group) and pre-treated either with control (pre-immune) or anti-HMG1 serum (as made in Example 4) 30 minutes before administration (intraperitoneally) of a lethal dose of LPS (50 mg/kg in 1 x PBS). Other experimental groups received additional doses of anti-HMG1 serum at +12 or, +12, and +36 hours after LPS administration. Animals were observed for appearance and survival for at least two weeks.

Polyclonal antibodies against recombinant HMG1 were generated in rabbits, and antiserum was assayed for specificity and titer by ELISA and Western blotting procedures. The polyclonal antiserum immunospecifically recognized (bound to) recombinant HMG1 in Western blot analysis, for instance, and discriminated rHMG1 from other proteins in both crude bacterial lysates and as a purified protein that had been diluted into mouse serum. Using chemiluminescence-amplified detection methods in Western blotting analysis, polyclonal anti-HMG1 antiserum at dilutions up to 1:1000 was useful to detect as little as 50 pg rHMG1 protein. Administration of anti-HMG1 antiserum in the indicated (Figure 2A) amounts at -0.5 (if one dose), -0.5 and 12 (if two doses), or -0.5, 12 and 36 (if three doses) hours relative to LPS challenge (at time 0) was protective against LPS-induced lethality, and repeated dosing schedules provided better protection.

Figure 2B illustrates that rHMG1 causes dose-dependent lethality in endotoxic mice. Male Balb/C mice (20-23 grams) were randomized in groups of ten to receive LPS (3.15 mg/kg; a non-lethal dose) alone or in combination with purified recombinant HMG1 protein.

Administration of HMGI at the indicated doses 2, 16, 28 and 40 hours after LPS challenge significantly increased the lethality of the underlying endotoxemia.

Figure 2C illustrates the independent lethal toxicity of HMGI as a function of dose. Purified rHMGI was administered to male Balb/C mice (five mice per treatment group) as a single i.p. bolus at the indicated dosage. Mice were observed for at least 48 hours, and 60% of mice treated with rHMGI at a dose of 500 µg/mouse died within 24 hours of rHMGI challenge, indicating a single dose LD₅₀ of less than 500 µg/mouse.

The protection conferred by anti-HMGI antibodies was specific, because administration of pre-immune serum, which showed no immunospecific reactivity to HMGI on Western blots, did not spare subjects from LPS-mediated mortality (Figure 2A). Moreover, HMGI-specific antibodies did not cross-react with other macrophage-derived cytokines (*e.g.* IL-1 and TNF), eliminating the possibility that antibodies conferred protection by binding and thereby neutralizing these mediators. Protection against sepsis, sepsis associated pathogenesis and sepsis-related diseases involving activation of pro-inflammatory cytokine cascades may be improved by combination therapy targeted against more than one component of the cytokine cascade. Antagonists of HMGI in this regard can be combined with specific antagonists of TNF, IL-1, MIF and other inflammatory mediators, or with more broadly active antagonists of inflammatory responses that inhibit multiple components of the inflammatory cascade (*e.g.*, aspirin, NSAIDS, anti-inflammatory steroids, etc.), to provide even more effective therapeutic modalities. Protection against LPS toxicity was antibody dose-related, and more frequent dosing with higher amounts of antibody reduced mortality by up to 70% (Figure 2A). Mice were observed for at least 2 weeks in all experiments, and no late mortality occurred, indicating that anti-HMGI antibody treatment confers lasting protection against LPS lethality, and does not merely delay the time of death.

Example 7: HMGI in human disease

This example provides data that establish an association between HMGI and human sepsis, and thereby support an indication for using HMGI antagonists generally and anti-HMGI antibodies in particular in human sepsis and related conditions of cytokine toxicity. Serum HMGI levels in normal healthy individuals and critically ill patients were measured using the polyclonal antibodies generated as in Example 4 in a Western blot format with reference to a standard curve of rHMGI. HMGI was not detectable in normal controls, but accumulated to high levels in critically ill patients with sepsis (Table 2).

Table 2. Serum appearance of HMGI in sepsis patients.

Patient (#)	Age (year)	HMGI (ng/ml)	Diagnosis	Outcome
1	27	<d.l.	Normal	Healthy
2	34	<d.l.	Normal	Healthy
3	35	<d.l.	Normal	Healthy
4	36	<d.l.	Normal	Healthy

5	61	<d.l.	Normal	Healthy
6	31	<d.l.	Normal	Healthy
7	55	10	Sepsis, anastomotic leak	Recovered
8	70	7-20	Sepsis, colonic perforation	Recovered
9	44	10-60	Sepsis, MOF, spinal reconstruction	Died
10	60	>120	Sepsis, MOF, perforated gastric ulcer	Died
11	47	>120	Sepsis, MOF, pneumonia	Died

Note: <d.l. - below detection limit; MOF - Multiple Organ Failure.

These data show that elevated serum HMG1 levels are observed in patients with sepsis, and the highest levels of serum HMG1 are observed in lethal cases (Table 2). These data further indicate the therapeutic importance of HMG1 antagonists in sepsis and also provide evidence for the diagnostic utility of an assay for sepsis and severity (*i.e.*, potential lethality) of sepsis by measuring serum concentrations of HMG1. This diagnostic assay is also useful for diagnosing the severity of allied conditions involving activation of the inflammatory cytokine cascade.

Additional subjects were screened for serum HMG1 levels in association with lethal versus non-lethal sepsis, with results (cumulative with Table 2) as described in Figure 6. The data summarized in Figure 6 represent serum samples obtained from eight healthy subjects and twenty-five septic patients infected with Gram positive [*Bacillus fragilis* (1 patient), *Enterococcus faecalis* (1 patient), *Streptococcus pneumonia* (4 patients), *Listeria monocytogenes* (1 patient), or *Staphylococcus aureus* (2 patients)], Gram negative [*Escherichia coli* (7 patients), *Klebsiella pneumonia* (1 patient), *Acinetobacter calcoaceticus* (1 patient), *Pseudomonas aeruginosa* (1 patient), *Fusobacterium nucleatum* (1 patient), *Citrobacter freundii* (1 patient)], or unidentified pathogens (5 patients). Serum was fractionated by SDS-PAGE gel electrophoresis, and HMG1 levels were determined by Western blotting analysis with reference to standard curves of purified rHMG1 diluted in normal human serum. The detection limit by Western blotting analysis is 50 pg. Note that HMG1 is not detectable in normal controls, but significantly increased in septic patients. The average level of HMG1 in serum of non-surviving septic patients (N = 13 patients, mean HMG1 level = 83.7 ± 22.3 ng/ml) is significantly higher than in survivors (N = 12, mean HMG1 level = 25.2 ± 15.1 ng/ml, $P < 0.05$). These data provide direct evidence of the utility of screening tissue (including, without limitation blood or serum) samples for HMG1 sequences (protein or nucleic acid) as a diagnostic and prognostic indicator of the presence of sepsis and related disorders of cytokine activation and of the severity and likely clinical course of such diseases and conditions.

Example 8: HMG1 induces pro-inflammatory mediators and weight loss

The present results provide evidence that HMG1 is a late released mediator element of the inflammatory cytokine cascade. Addition of recombinant HMG1 to primary human peripheral blood mononuclear cells led to the dose-dependent induction of TNF within four

hours after stimulation (Figure 3A). This stimulation by recombinant HMG1 of TNF release by HuPBMCs was not due to LPS contamination because: (i) purified recombinant HMG1 was not contaminated by LPS as judged by an LAL endotoxin assay; ii) addition of the LPS-neutralizing agent polymyxin B did not affect HMG1-induced TNF release; and iii) proteolytic
5 cleavage of recombinant HMG1 preparations with trypsin completely abolished the TNF release activity for the PBMC cultures. HMG1 stimulation also induced macrophages to release nitric oxide (NO).

To confirm that HMG1 induced serum TNF release *in vivo*, purified recombinant HMG1 was administered intraperitoneally to Balb/C mice, and blood samples were collected
10 to be assayed for TNF by the L929 assay. As shown in Figure 3B, TNF was not detectable in serum of control animals, but was significantly increased two hours after administration of recombinant HMG1 protein.

Repetitive administration of recombinant gene product of the HMG1 gene (100 µg/mouse/day) caused significant body weight loss (Figure 4) in mice. Without limitation as
15 to mechanism and without being bound by theory, these data are consistent with the hypothesis that HMG1 acts as a feed-forward stimulator of the pro-inflammatory cascade under both *in vitro* and *in vivo* conditions. These *in vivo* data in a predictive model of weight loss also provide predictive evidence that a pharmaceutical formulation comprising HMG1, or a therapeutically active fragment thereof, is an effective weight loss therapy.

20 Example 9: *In vivo* sources of HMG1

Serum HMG1 levels in hypophysectomized versus control rats also were measured by quantitation of Western blot intensities as described above. There were significantly higher HMG1 levels within 12 hours after endotoxic challenge (LPS at 1.0 mg/kg) in
hypophysectomized rats (approximately 75 ng/ml) as compared to controls (approximately 25
25 ng/ml). These results indicate that pituicytes are not the major source of serum HMG1 levels and that macrophages may play a quantitatively more important role.

We claim:

1. A pharmaceutical composition for treating conditions (diseases) characterized by activation of the inflammatory cytokine cascade, comprising an effective amount of an antagonist or inhibitor of HMG1.
- 5 2. A pharmaceutical composition for treating sepsis and related conditions, comprising an effective amount of an HMG1 antagonist.
3. The pharmaceutical composition of claims 1 or 2 wherein the HMG1 antagonist is selected from the group consisting of antibodies that bind to HMG1, HMG1 antisense sequences and HMG1 receptor antagonists.
- 10 4. A method for treating a condition characterized by activation of the inflammatory cytokine cascade, comprising administering an effective amount of an HMG1 antagonist.
5. A method for treating sepsis and related conditions involving activation of the inflammatory cytokine cascade syndrome, comprising administering an effective amount of an
15 HMG1 antagonist.
6. The method of claims 4 or 5 further comprising administering a second agent in combination with the HMG1 antagonist, wherein the second agent is an antagonist of an early sepsis mediator.
7. The methods of claim 6 wherein the second agent is an antagonist of a cytokine
20 selected from the group consisting of TNF, IL-1 α , IL-1 β , MIF and IL-6.
8. The method of claim 7 wherein the second agent is an antibody to TNF or MIF or an IL-1 receptor antagonist (IL-1ra).
7. A diagnostic and prognostic method for monitoring the severity and predicting the likely clinical course of sepsis and related conditions for a patient exhibiting shock-like
25 symptoms or at risk to exhibit symptoms associated with conditions characterized by activation of the inflammatory cascade, comprising measuring the concentration of HMG1 in a sample, and comparing that concentration to a standard for HMG1 representative of a normal concentration range of HMG1 in a like sample, whereby higher levels of HMG1 are indicative of poor prognosis or the likelihood of toxic reactions.
- 30 8. The diagnostic or prognostic method of claim 7 wherein the sample is a serum sample.
9. A diagnostic method for monitoring the diagnosing or monitoring the severity of sepsis or septic shock, comprising measuring a serum concentration of HMG1 in a patient at risk to exhibit or exhibiting sepsis or septic shock-like symptoms, whereby higher levels of
35 HMG1 are indicative of a diagnosis of sepsis or septic shock or a poor prognosis.
10. A pharmaceutical composition for effecting weight loss or treating obesity, comprising an effective amount of HMG1 or a therapeutically active fragment thereof.
11. A method for effecting weight loss or treating obesity, comprising administering an effective amount of HMG1 or a therapeutically active fragment thereof.

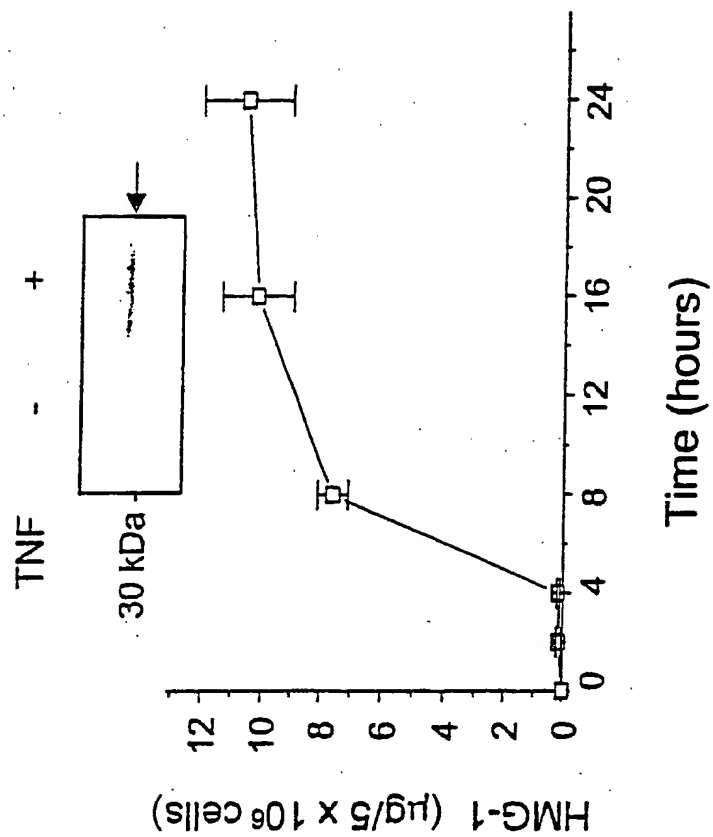


Fig. 1a

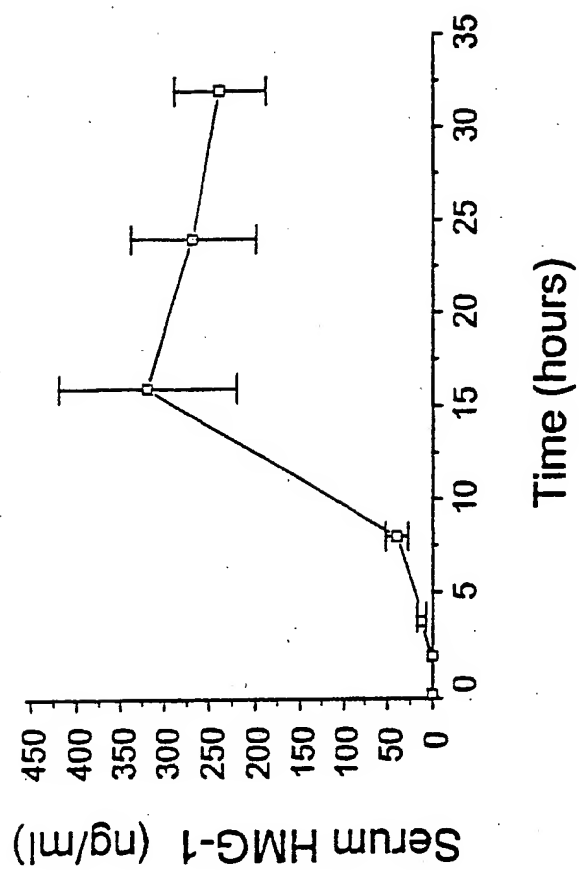


Fig. 1b

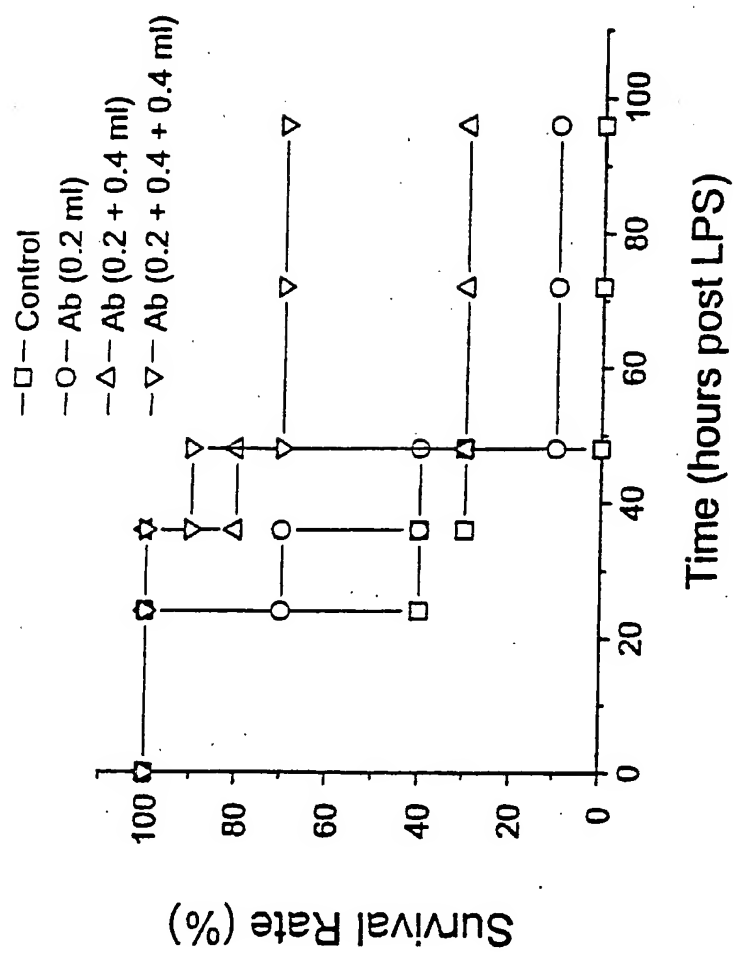


Fig. 2a

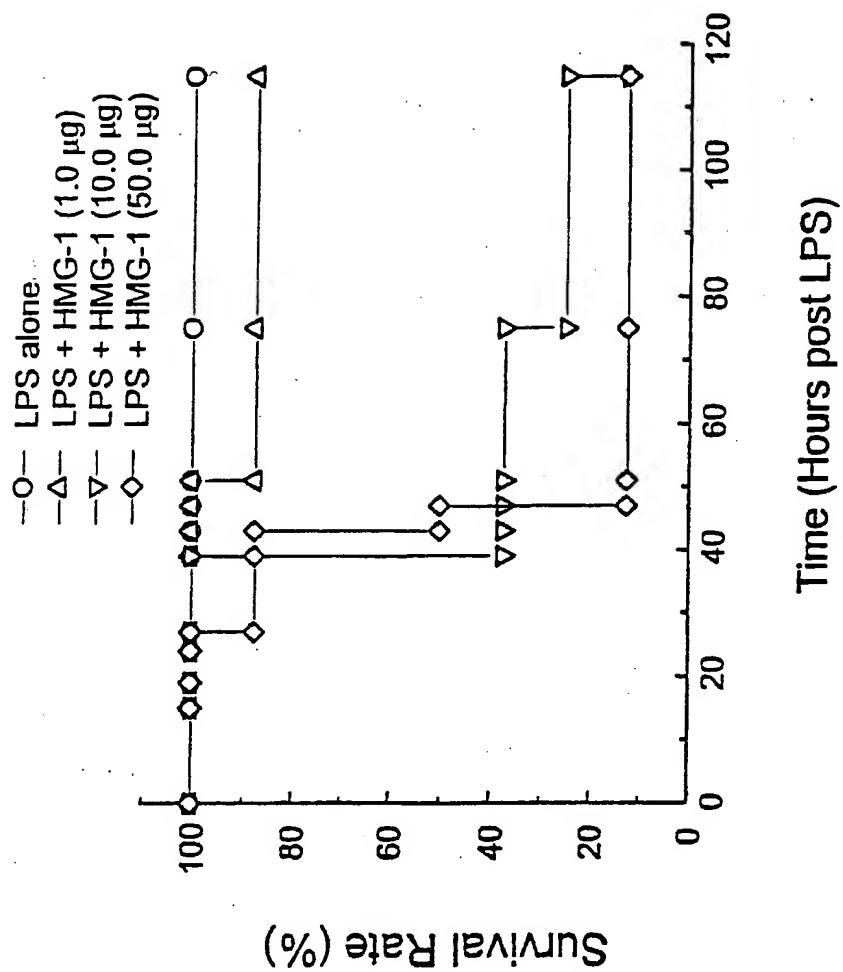


Fig. 2b

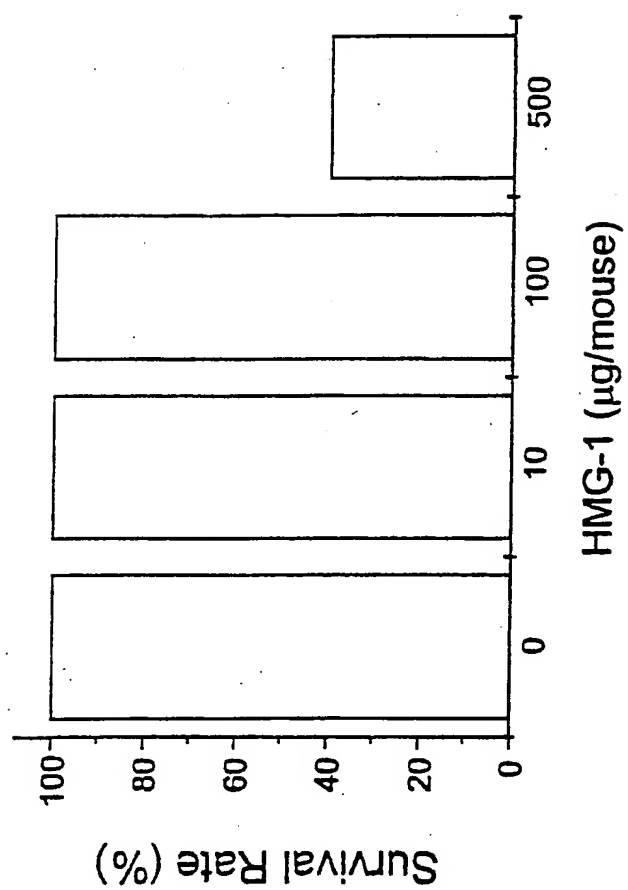


Fig. 2c

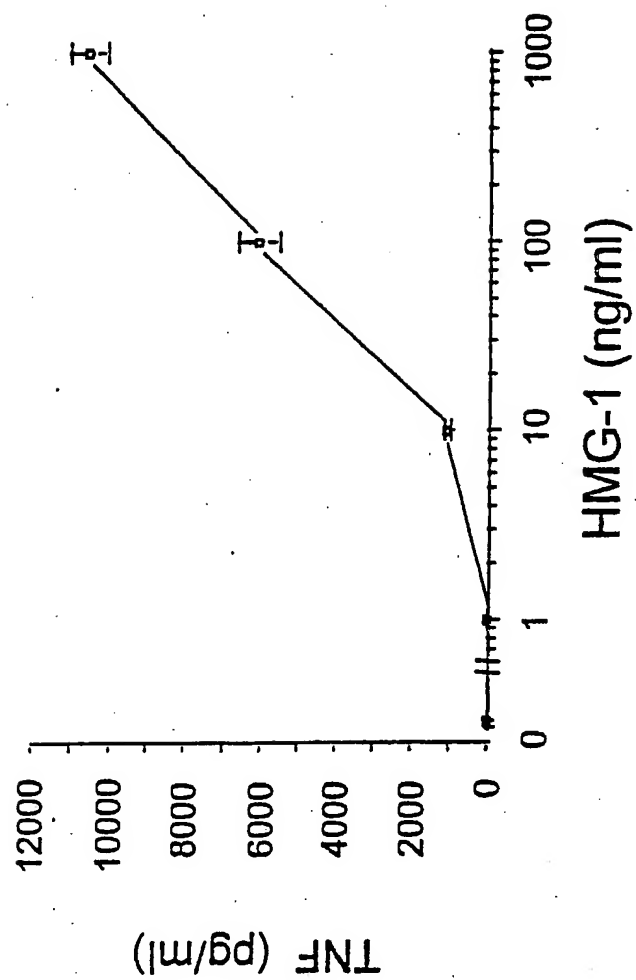


Fig. 3a

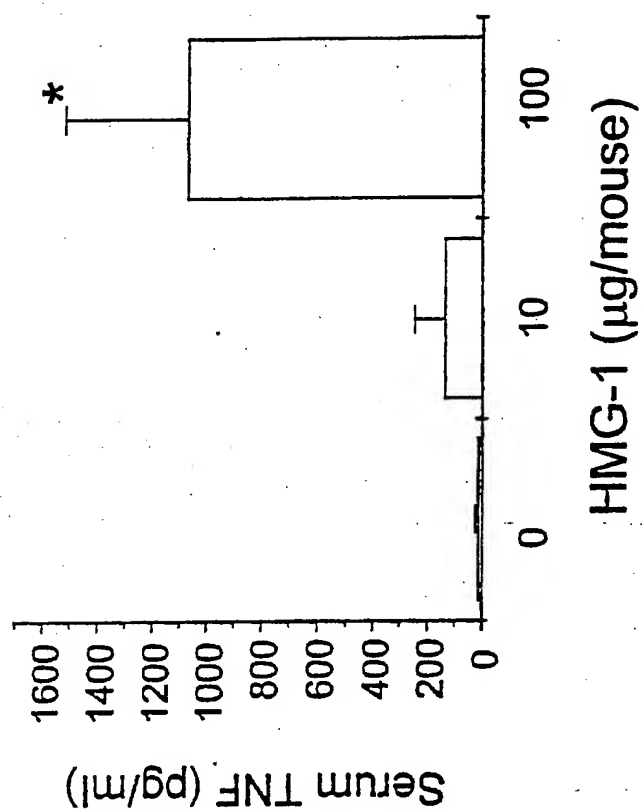


Fig. 3b

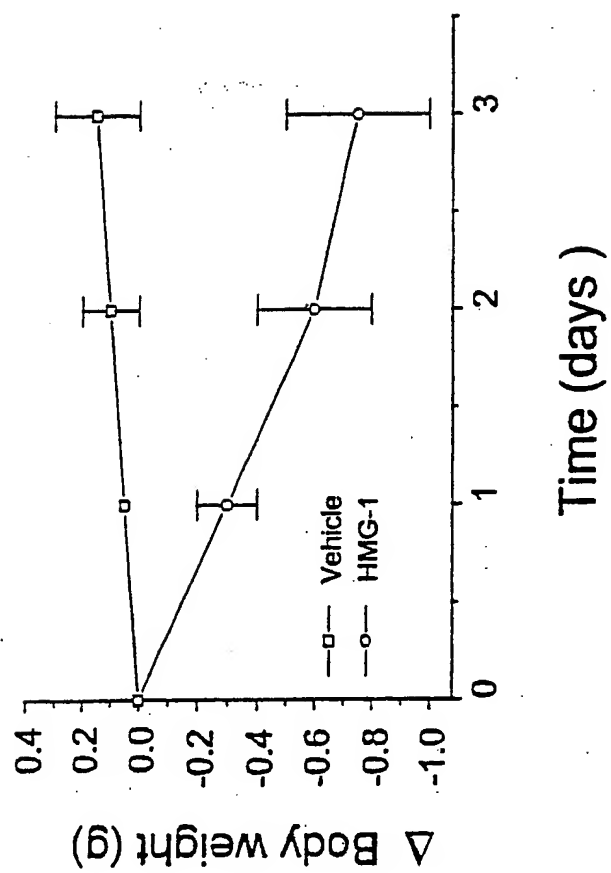


Fig. 4

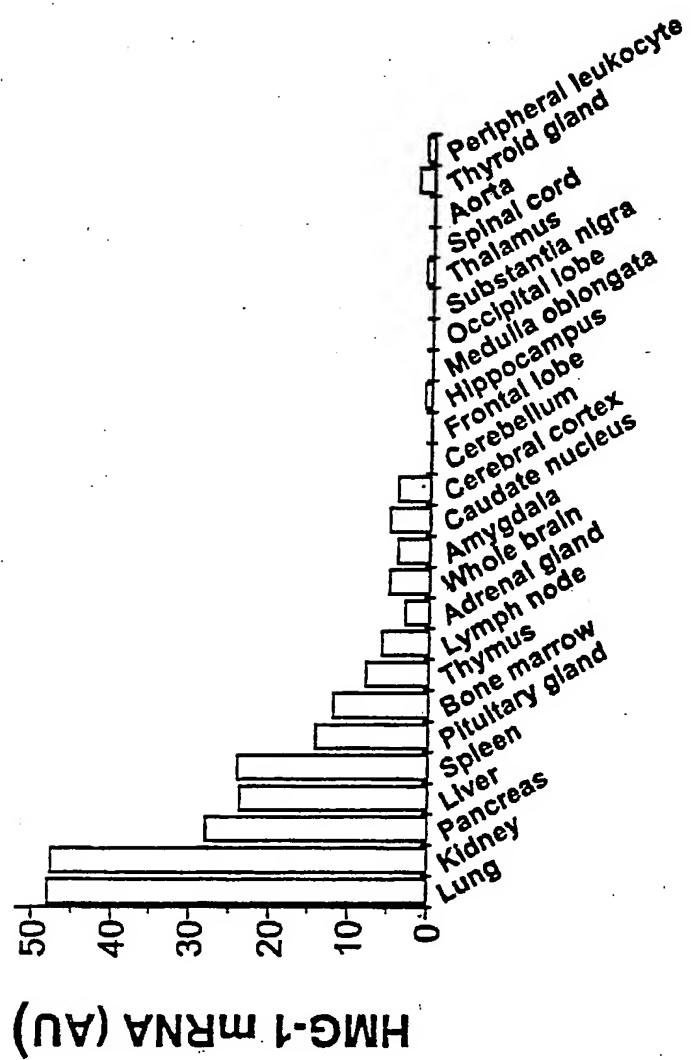


Fig. 5

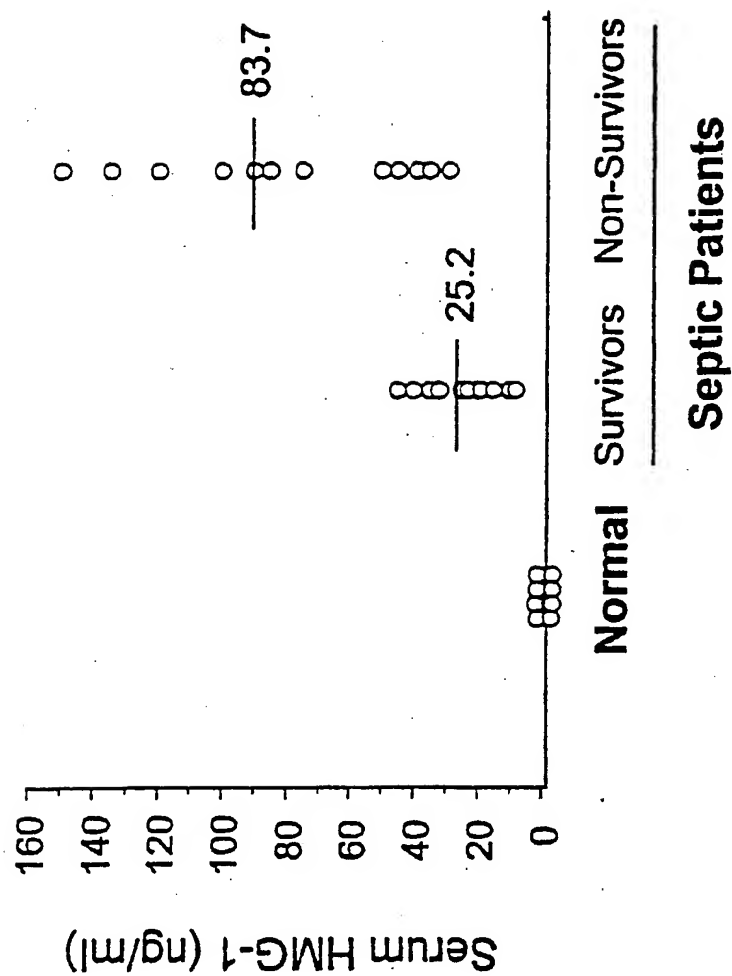


Fig. 6

SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT: THE PICOWER INSTITUTE FOR MEDICAL RESEARCH
(ii) TITLE OF INVENTION: Antagonists of HMGI for Treating Inflammatory Conditions

(iii) NUMBER OF SEQUENCES: 5

(iv) CORRESPONDENCE ADDRESS:

(A) ADDRESSEE: DAVIS WRIGHT TREMAINE
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(v) COMPUTER READABLE FORM:

(A) MEDIUM TYPE: Floppy disk
(B) COMPUTER: PC compatible
(C) OPERATING SYSTEM: Windows95
(D) SOFTWARE: Word

(vi) CURRENT APPLICATION DATA:

(A) APPLICATION NUMBER: PCT/US00/03583
(B) FILING DATE: 14 February 2000
(C) CLASSIFICATION:

(viii) ATTORNEY/AGENT INFORMATION:

(A) NAME: Oster, Jeffrey B.
(B) REGISTRATION NUMBER: 32,585
(C) REFERENCE/DOCKET NUMBER: 1201WO

(ix) TELECOMMUNICATION INFORMATION:

(A) TELEPHONE: 206 628 7711
(B) TELEFAX: 206 628 7699

(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 14
(B) TYPE: amino acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: HMGI N terminal

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

Gly Lys Gly Asp Pro Lys Lys Pro Arg Gly Lys Met Ser Ser 14
 5 10

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 42
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: PCR primer

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

CCCCGCGGATC CATCGAGGGA AGGATGGGCA AAGGAGATCC TA 42

(2) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 31
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: PCR Primer

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

CCCGCAAGCT TATTCATCAT CATCATCTTC T 31

(2) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 15
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: HMGl N terminus

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

Gly	Lys	Gly	Asp	Pro	Lys	Lys	Pro	Arg	Gly	Lys	Met	Ser	Ser	Cys	15
					5				10					15	

(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 42
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: HMGl cDNA region spanning initiator sequence

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

GAGGAAAAAT AACTAAACAT GGGCAAAGGA GATCCTAAGA AG 42

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/03583

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : A61K 38/00; C07K 1/00; C07H 21/04; C12P 21/06; G01N 33/566

US CL : 514/2; 530/350, 388.22; 536/23.5; 435/69.1; 436/501

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 514/2; 530/350, 388.22; 536/23.5; 435/69.1; 436/501

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SPARATORE et al. Extracellular high-mobility group 1 protein is essential for murine erythroleukemia cell differentiation. Biochem. J. August 1996, Vol. 320, pages 253-256, see the Abstract.	1-3
A	WANG, H. et al. HMG-1 as a late mediator of endotoxin lethality in mice. Science. 09 July 1999, Vol. 285, pages 248-251, see the entire document.	1-8



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
E earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Z* document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means	
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

28 MARCH 2001

Date of mailing of the international search report

23 MAY 2001

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

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Authorized officer

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Telephone No. (703) 308-0196

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/03583

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-8

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/03583

B. FIELDS SEARCHED

Electronic data bases consulted (Name of data base and where practicable terms used):

STN: MEDLINE, BIOSIS, BIOTECHNO; WEST 2.0

search terms: HMG1 antagonist, anti-HMG1, antibody, sepsis, inflammatory cascade, high mobility group, amphoterin, anti-amphoterin

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING

This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I, claim(s) 1-8, drawn to a pharmaceutical composition for treating disease comprising an antagonist of HMG1 and a method for treating disease characterized by activation of the inflammatory cytokine cascade.

Group II, claim(s) 9-11, drawn to a diagnostic method.

Group III, claim(s) 12, drawn to a pharmaceutical composition for effecting weight loss.

Group IV, claim 13, drawn to a method for effecting weight loss.

This application contains claims directed to more than one species of the generic invention. These species are deemed to lack Unity of Invention because they are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for more than one species to be searched, the appropriate additional search fees must be paid. The species are as follows:

A pharmaceutical composition comprising:

- i) an antibody,
- ii) an antisense nucleic acid,
- iii) and HMG1 receptor antagonist

The claims are deemed to correspond to the species listed above in the following manner:

Claims 1-8 require the above species of compounds

The following claims are generic: 1-8

The inventions listed as Groups do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: Pursuant to 37 C.F.R. 1.475(d), this Authority considers that the main invention in the instant application comprises the first recited product, a pharmaceutical composition comprising and HMG1 receptor antagonist and the first recited method of using that product, namely in the process of treating a condition characterized by activation of the inflammatory cytokine cascade. Further, pursuant to 37 C.F.R. 1.475(b)-(d), the ISA/US considers that the materially and functionally dissimilar products of Groups III and the additional methods of Groups II and IV do not correspond to the main invention. This Authority therefore considers that the several inventions do not share a special technical feature within the meaning of PCT Rule 13.2 and thus do not relate to a single general inventive concept within the meaning of PCT Rule 13.1.

The species listed above do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, the species lack the same or corresponding special technical features for the following reasons: Antibodies, nucleic acids and molecules which function as HMG1 receptor antagonists are functionally and structurally distinct compounds.